The
ENGINEERS' DIGEST

REVIEW OF WORLD ENGINEERING PROGRESS

VOL. X. No. 11 NOVEMBER, 1949

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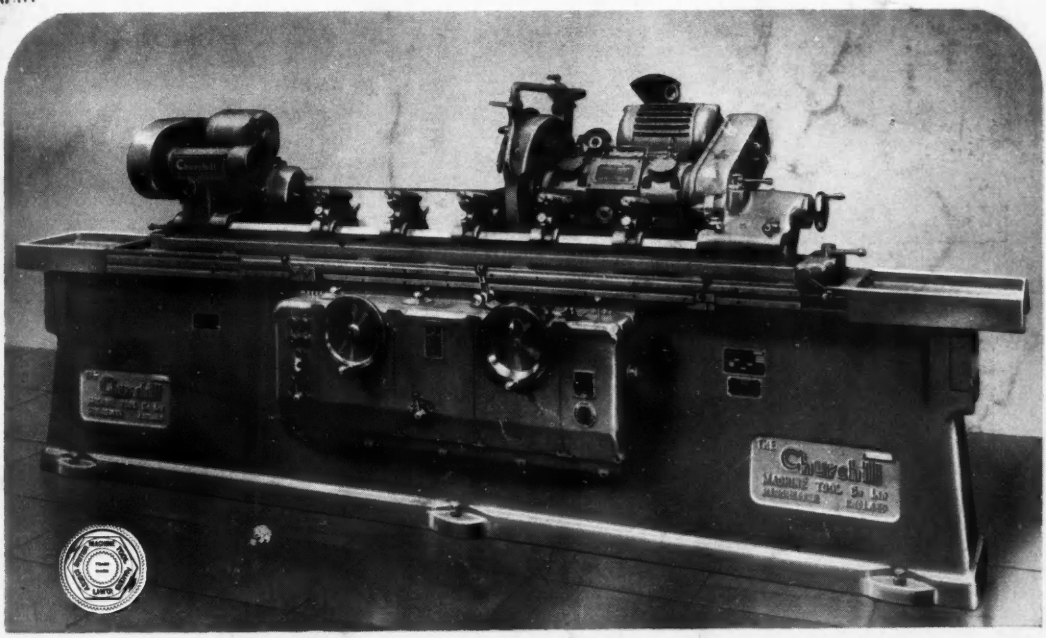

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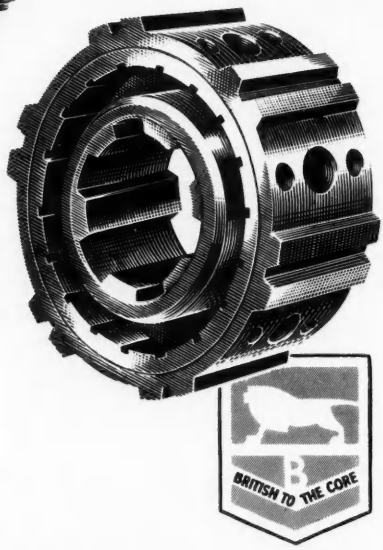

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THE ENGINEERS' DIGEST

REVIEW OF WORLD ENGINEERING PROGRESS

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IN THIS ISSUE

THE deposition of a film of liquid petrol on the walls of the intake pipe, caused by low temperatures and high boiling fractions, may have harmful effects on the operation of a petrol engine. Liquid petrol carried into the cylinder will not only be uneconomical but also wash the lubricating oil film off the cylinder walls especially at the top of the cylinder, and this is particularly harmful, as maximum wear usually occurs near the top position of the first piston ring, even under normal lubricating conditions. Furthermore, the petrol carried into the crankcase will cause dilution of the lubricating oil, thus reducing its viscosity and, consequently, its load carrying capacity. The deposition of fuel in the intake manifold of a multi-cylinder engine may also upset the mixture distribution, and especially the octane number of the fuel reaching individual cylinders owing to the dropping out of ethyl fluid, added to present-day fuel in order to increase its octane number.

The various factors influencing the deposition of a liquid film of petrol have been the subject of a research in the Special Laboratory of the Russian Automobile and Tractor Industry. As will be seen in the article published on page 393 the author has developed a special fuel trap which allows of measuring the amount of petrol deposited in the intake pipe and he suggests that a fuel trap based on the same principles should be developed for petrol engines which have to operate under adverse climatic conditions.

* * *

The article by R. Feldtkeller and E. Stegmaier, of the Stuttgart Institute of Technology, investigates the effect of premagnetisation with a constant magnetic field on the complex permeability of laminated cores. The diagrams and calculations are simplified by introducing the reciprocal of the complex permeability, and a formula is evolved for the " inhomogeneity factor " which takes account of the variation of the local permeability within the material. Experimental curves are also given and these confirm the validity of this theory on the effect of premagnetisation on eddy currents.

* * *

Electrolytic polishing has rapidly established itself in industry and research. With copper alloys, however, preparation of the specimen must be carried out very carefully, and polishing takes a fairly long time if a good surface is to be obtained. The authors of the article on page 381 have overcome these disadvantages by oscillating the specimen in the electrolytic bath. If the polarity of the electrodes is reversed after polishing, the polished surface can be plated in the polishing bath. The authors use this fact in connection with the difference in concentration produced during the polishing process and obtain very thin copper deposits by just short-circuiting the electrodes. The thickness of the deposit is not uniform, but depends on the grain orientation. Differences in colour thus give a good contrast of grains under the microscope and the effect is equal to that of an etching action. This method has the advantage over the usual etching reagents that the time of application, and, therefore, the contrast obtained, can be very closely controlled and identically reproduced.

* * *

The widespread use of high-volatile bituminous coals in conventional handfired heating and cooking devices has resulted in serious atmospheric pollution in many cities, and in consequence a general demand for smoke abatement campaigns has arisen. Although most people in Great Britain still prefer open fireplaces in their homes, nobody can deny that smokeless homes would be highly desirable. They would be welcomed not only for reasons of personal comfort, but also from the national point of view, as re-designing of coal fires would result in a substantial saving of coal. Particular importance should, therefore, be attached to experiments on a smokeless coal heater carried out in the United States, and these are described on page 389.

Inventors have been trying for nearly 100 years to develop practicable handfired smokeless coal heaters. However, the fact that there was no such equipment on the market when the studies at the University of Illinois began, that is, in 1935, constituted prima facie evidence that some of their problems had not been solved. Later, in 1941, a separate investigation was started at the Battelle Memorial Institute, with the same objectives as the one previously mentioned, under the joint sponsorship of Bituminous Coal Research and a group of stove manufacturers.

Largely due to the co-operation of the National Warm Air Heating and Air Conditioning Association, two individual furnace companies, and a manufacturer of firebricks, the Illinois Smokeless Furnace has now been developed through the many necessary stages from the conception of the incorporated design principle to the actual production and sale of commercial units.

GERMANY

The Effect of Premagnetisation on the Complex Permeability of Coil Cores

By R. FELDTKELLER and E. STEGMAIER. (From *Frequenz*, Vol. 2, No. 5, May, 1949, pp. 121-130, 17 illustrations.)

FIGURES 1 and 2 show the effect of premagnetisation on the complex permeability of silicon iron, 0·35 mm thick (standard dynamo lamination No. IV). With increasing premagnetisation, the diagram formed by the curves of constant field strength and constant frequency becomes smaller in size and is shifted towards the origin of the complex plane. This indicates that the influence of hysteresis and eddy currents is considerably reduced with premagnetisation due to a constant magnetic field.

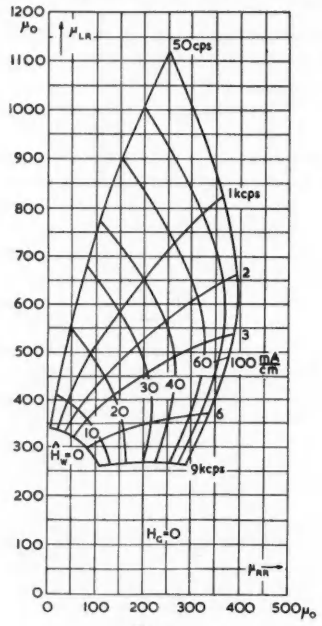


Fig. 1

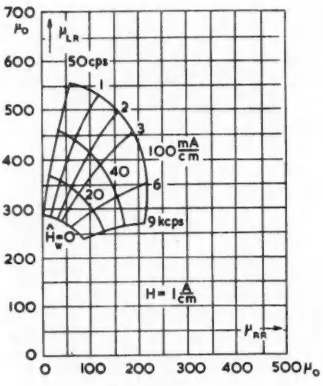


Fig. 2

Figs. 1 and 2. **Complex permeability of dynamo lamination No. IV.**

Components μ_{LR} and μ_{RR} as functions of frequency f and alternating field strength $\hat{H}_W$, for constant field premagnetisations $H_G = 0$ and $H_G = 1{\cdot}0$ A/cm.

The effect is more easily appreciated if we consider the reciprocal of complex permeability

$$\frac{1}{\bar{\mu}} = \frac{1}{\mu_{LP}} + j\,\frac{1}{\mu_{PR}} \qquad .. \qquad .. \qquad (1)$$

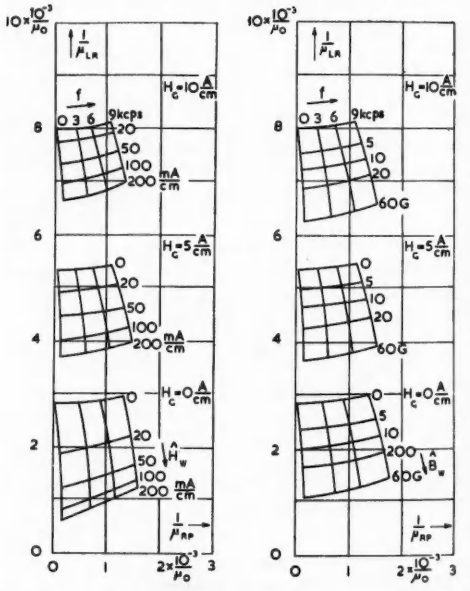
as shown in Fig. 3, with the frequency f and the amplitude of the alternating field strength $\hat{H}_W$ as parameters. The diagrams show that premagnetisation shifts the curve networks parallel to the ordinate axis. This is even more apparent in Fig. 4, in which the alternating magnetic induction $\hat{B}_W$ is used as a parameter instead of $\hat{H}_W$.

Thus, owing to premagnetisation, $1/\bar{\mu}$ is increased by a real quantity which is practically independent of the parameters $\hat{B}_W$ and f, and varies with the type of alloy.

1. THE RECIPROCAL OF REVERSIBLE PERMEABILITY

The point at the lower left-hand corner of the diagrams, related to the values $f = 0$ and $\hat{B}_W = 0$, is only obtainable by extrapolation, and corresponds to the reciprocal $1/\mu_{rev}$ of the reversible permeability. Thus, the value of $1/\mu_{rev}$ depends on the premagnetisation H_G and the type of material used.

The value of μ_{rev} determines the slope of a small hysteresis loop obtained by superimposing a very



Figs. 3 and 4. **Reciprocal $1/\mu$ of complex permeability for dynamo lamination No. IV, 0·35 mm thick, for various premagnetisations.**

Parameters: Fig. 3: Frequency f, and alternating field strength $\hat{H}_W$. Fig. 4: Frequency f, and alternating magnetic induction $\hat{B}_W$.

small alternating field strength $\hat{H}_W$ upon a constant field H_G. Reproducible results and stable hysteresis loops can be obtained by first switching on the constant field, and then the superimposed alternating field of sufficiently high frequency, up to a peak value of about 200 mA/cm.

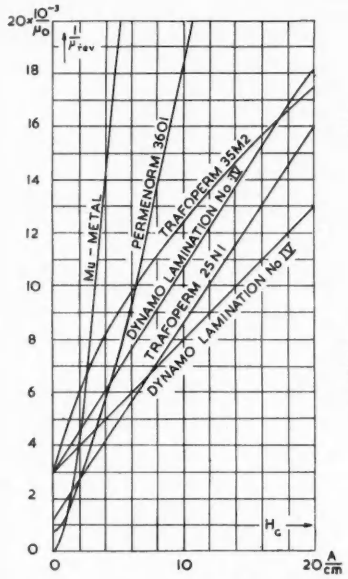


Fig. 5 (left). **Reciprocals of reversible permeability μ_{rev} as functions of constant field strength H_G.**

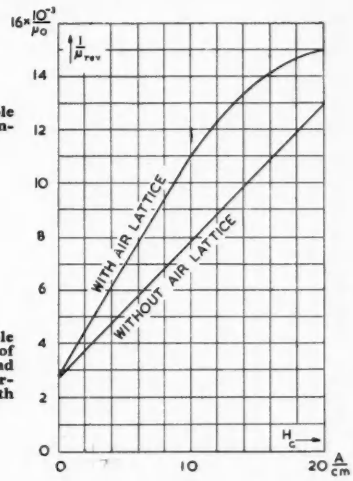


Fig. 6 (right). **Reciprocals of reversible permeability of an M-42 core of dynamo lamination No. IV, with and without air lattices formed by overlapping layers of laminations with an air-gap 0·5 mm wide.**

Fig. 5 shows for various materials the measured values of $1/\mu_{rev}$ for constant field strengths H_G of 0 to 20 mA/cm, which can be generated for fairly long periods of time in " E " and " M " type cores, without excessive overheating of the windings. Trafoperm 25.N.I. is a 2·1 per cent silicon-iron alloy (Heraeus), Permenorm 3601 (Heraeus) a 36 per cent nickel-iron alloy, and Mu-metal a 76 per cent nickel-iron alloy.

The curves of Fig. 5 are valid only for cores made up of laminations without an air gap. When punchings with an air gap are used, and arranged to overlap so as to render the gaps ineffective, two air-and-metal lattices are formed, through which the constant magnetic flux penetrates. The iron within the lattices saturates much more rapidly than the iron outside the lattices. This is why the inductance of a coil with an iron core of this type decreases more rapidly with premagnetisation, and the use of such cores can lead to inaccurate results for $1/\mu_{rev}$ (see Fig. 6).

2. EDDY CURRENTS

When $\hat{B}_W$ tends towards zero, the effect of hysteresis on complex permeability vanishes, and only the effect of the eddy currents remains. According to the theory of eddy currents, when the alternating flux has a constant amplitude, the effect of the eddy currents on $1/\bar{\mu}$ is independent of the premagnetisation. This theory is largely substantiated by measurements.

A closer examination of Fig. 4 shows, however, that for extremely low values of $\hat{B}_W$, with increasing premagnetisation, the effect of the eddy currents on $1/\bar{\mu}$ decreases, although the decrease is so gradual that accurate measurements are difficult. Thus, for the lamination considered, at 9 kcps frequency, the value of the reciprocal parallel-resistance permeability is $1/\mu_{PR} = 1{\cdot}35 \times 10^{-3}/\mu_0$ when $H_G = 0$, as compared with $1/\mu_{PR} = 1{\cdot}05 \times 10^{-3}/\mu_0$ when $H_G = 10$ A/cm at the same frequency. The eddy current decrease in this region is, therefore, approximately 20 per cent. A study of various types of laminations has shown, however, that an increase of the eddy currents is equally likely to occur.

According to the theory of eddy currents developed by Wolman [1], the reciprocal of parallel-resistance permeability is determined by

$$1/\mu_{PR} = \omega d_E^2/(12\rho_E) \quad .. \quad .. \quad (2)$$

for frequencies below the " limit frequency " of eddy currents. In this formula, $\omega = 2\pi \times$ frequency, $d_E =$ lamination thickness, $\rho_E =$ resistivity of laminations. Thus, $1/\mu_{PR}$ is not a function of the reversible permeability μ_{rev}.

In view of the fact that d_E does not depend on premagnetisation, and that ρ_E for silicon iron increases by only about 1 per cent up to the saturation point [2], one might be inclined to infer from eq. (2) that $1/\mu_{PR}$ is independent of premagnetisation. Test results indicate, however, that this is not the case, and Fig. 4 shows that, when $H_G = 10$ A/cm, the value of $1/\mu_{PR}$ is 20 per cent lower. It is thus necessary to modify eq. (2) by means of a suitable correction factor.

The effect of premagnetisation on $1/\mu_{PR}$ can be explained if we assume that reversible permeability is not affected by the premagnetisation H_G in the same way at the centre of the lamination as in its outer layers. Consider, for instance, a case where the value of μ_{rev} decreases to $100\mu_0$ at the surface, and to $150\mu_0$ in the inner layers of the lamination, when $H_G = 10$ A/cm. The results of an inductance measurement may indicate for μ_{rev} a value in the vicinity of $125\mu_0$. This variation of μ corresponds to an inhomogeneous induction and a non-uniform distribution of eddy-current density, differing from that of a homogeneous lamination with the same permeability value.

This difference is illustrated in Fig. 7, where the " local permeability " $\mu(x)$ is shown as a function of the distance x from the centre of the lamination. Furthermore, the eddy-current density $j_W(x)$, instead of being a straight line as in the homogeneous case (dotted line in Fig. 7b), follows a curve which is proportional to $Ax + Bx^2$ (solid line in Fig. 7b). The maximum value j_0 is the same in both cases, since the path of the eddy currents at the surface comprises the total flux going through the lamination.

[1] W. WOLMAN : *Zeits. f. techn. Physik*, Vol. 10, p. 595, 1929.
[2] O. STIERSTADT : *Zeits. f. techn. Physik*, Vol. 13, p. 65, 1932.

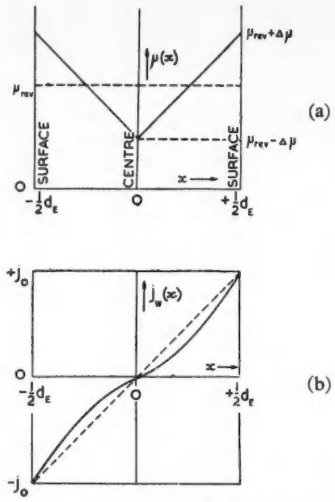


Fig. 7. **Variation of permeability and eddy-current density over the cross-section in homogeneous and non-homogeneous laminations.**

In the inhomogeneous lamination considered, the eddy-current density is, therefore, everywhere smaller than in the homogeneous lamination with the same reversible permeability, and this affects the $1/\mu_{PR}$ component of $1/\bar{\mu}$ in the same way as is indicated by the experimental curves of Fig. 4.

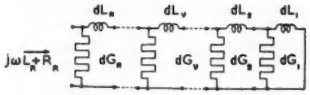


Fig. 8. **Equivalent circuit of a coil with laminated core.**

This effect can be calculated for sufficiently low frequencies, by considering the equivalent chain circuit of Fig. 8 for the coil. Let w = number of windings of the coil, m = number of laminations of the core, d_E = thickness of one lamination, b = lamination width, $m\ b\ d_E$ = total iron cross-section, l = length of the mean line of force. We imagine that the lamination is subdivided into thin layers symmetrically to the centre of the lamination. Let each half-lamination have n layers of a thickness

$$dx = d_E/(2n) \quad .. \quad .. \quad (3)$$

the layers being numbered from the centre outwards. The ν–th pair of layers at the distance $\pm x$ from the centre of the lamination contributes to the inductance of the coil with an amount

$$\begin{aligned} dL_\nu(x) &= w^2 m \mu(x) b\, d_E/(ln) \\ &= 2w^2 m \mu(x) b\, dx/l \quad .. \quad (4) \end{aligned}$$

and the corresponding parallel admittance of the equivalent circuit is

$$\begin{aligned} dG_\nu(x) &= d_E/[4\rho(x) w^2 mbn/l] \\ &= 2dx/[4w^2 m\rho(x) b/l] \quad .. \quad (5) \end{aligned}$$

The circuit impedance R_ν, determined by the ν first pairs of layers, is mainly reactive at very low frequencies; the reactance is

$$j\omega L_\nu = j\omega \int_0^x dx\, 2w^2 m\mu(x) b/l \quad .. \quad (6)$$

In parallel with this reactance is the very small admittance $dG_\nu(x)$. It has little effect on the reactive component, but adds to the real component a contribution

$$\begin{aligned} dR(x) &= Re\left[\frac{1}{j\omega L_\nu} + dG(x)\right]^{-1} \\ &= Re\left[j\omega L_\nu \Big/ [1 + j\omega L_\nu\ dG(x)]\right] \simeq (\omega L_\nu)^2\, dG(x) \end{aligned} \quad (7)$$

(where Re = real part of the complex quantity) and together with eqs. (5) and (6) this gives

$$dR(x) = \left[\omega w^2 m \frac{b}{l} 2 \int_0^x dx\, \mu(x)\right]^2 \frac{2dx}{w^2 m\, 4\, \rho(x)\, b/l}$$

$$= \omega^2 w^2 m\, 2 \frac{b}{l} \left[\int_0^x dx\, \mu(x)\right]^2 dx/[\rho(x)] \quad .. \quad (8)$$

The total active impedance of the coil is thus

$$R_R = \int_0^{d_E/2} dR(x) \quad .. \quad .. \quad (9)$$

and the total inductance is

$$L_R = w^2 m \frac{b}{l} 2 \int_0^{d_E/2} dx\, \mu(x) \quad .. \quad (10)$$

We shall now assume that only the permeability $\mu(x)$ and not the resistivity $\rho(x)$ is a function of position in the iron, since μ is affected to a much greater extent than ρ by premagnetisation. We thus write

$$\rho(x) = \rho_E = \text{constant} \quad .. \quad .. \quad (11)$$

and express $\mu(x)$ by

$$\mu(x) = \mu_1 + \mu_2 \left|\frac{x}{d_E/2}\right|^k \quad .. \quad (12)$$

which is symmetrical relatively to the centre of the lamination. The greater k is, the more the inhomogeneity is confined to the layers near the surface. The linear mean value of $\mu(x)$ is the reversible permeability

$$\begin{aligned} \mu_{rev} &= \frac{1}{(d_E/2)} \int_0^{d_E/2} dx \left[\mu_1 + \mu_2 \left|\frac{x}{d_E/2}\right|^k\right] \\ &= \mu_1 + \frac{1}{k+1}\mu_2 \quad .. \quad .. \quad .. \quad (13) \end{aligned}$$

The value of the integral occurring in eq. (8) is

$$\int_0^x dx\, \mu(x) = \mu_1 x + \frac{1}{k+1}\mu_2 x^{k+1} (d_E/2)^{-k} \quad .. \quad (14)$$

Therefore, the contribution of the ν–th pair of layers to the real component of impedance becomes

$$dR(x) = \omega^2 w^2 m \frac{2b}{l\rho_E}\left[\mu_1^2 x^2 + \frac{2}{k+1}\mu_1\mu_2 x^{k+2}(d_E/2)^{-k} + \left(\frac{1}{k+1}\mu_2 (d_E/2)^{-k}\right)^2 x^{2k+2}\right] dx \quad .. \quad (15)$$

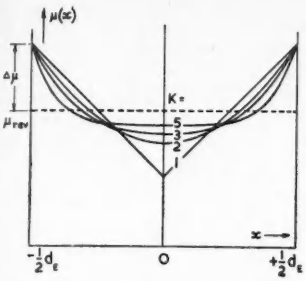


Fig. 9. **Assumed variation of permeability over the cross-section of the lamination.**
(μ_{max} at the surface).

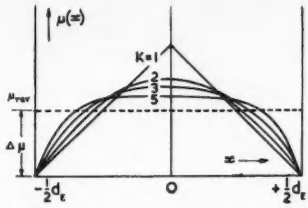


Fig. 10 (above). **Variation of permeability when μ is zero at the lamination surface.**

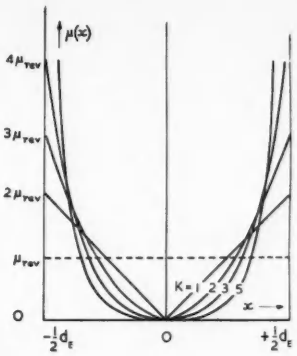


Fig. 11 (right). **Variation of permeability when μ is zero at the centre of the lamination.**

From eq. (9) we obtain for the real component of the coil impedance:

$$R_R = \omega^2 w^2 m \frac{b d_E^3}{12 l \rho_E} \left[\mu_1^2 + \frac{6}{(k+1)(k+3)} \mu_1 \mu_2 + \frac{3}{(2k+3)(k+1)^2} \mu_2^2 \right] \quad .. \quad .. \quad .. \quad (16)$$

With the inductance

$$L_R = w^2 \mu_{rev} m b d_E / l \quad .. \quad .. \quad (17)$$

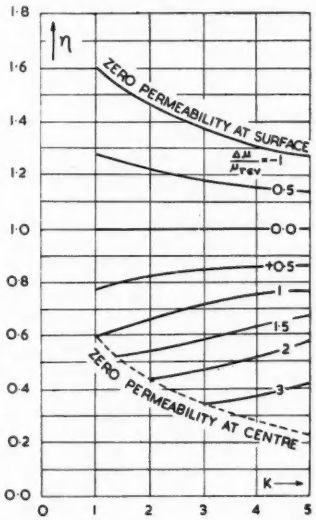


Fig. 12. **Inhomogeneity factor η used in calculating the effect of inhomogeneous permeability on eddy currents.**

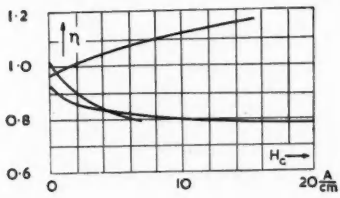


Fig. 13. **Measured values of inhomogeneity factor η.**
From measurements on standard dynamo laminations No. IV.

we thus obtain the parallel admittance

$$\frac{1}{R_P} = \frac{R_R}{\omega^2 L_R^2} = \frac{1}{w^2 m b d_E / l} \frac{d_E^2}{12 \rho_E} \left[\left(\frac{\mu_1}{\mu_{rev}} \right)^2 + \frac{6}{(k+1)(k+3)} \frac{\mu_1 \mu_2}{\mu_{rev}^2} + \frac{3}{(2k+3)(k+1)^2} \left(\frac{\mu_2}{\mu_{rev}} \right)^2 \right] \quad (18)$$

As, furthermore,

$$\frac{1}{R_P} = \frac{l}{\omega w^2 \mu_{PR} m b d_E} \quad .. \quad .. \quad (19)$$

the reciprocal of the parallel-resistance permeability becomes

$$\frac{1}{\mu_{PR}} = \frac{\omega d_E^2}{12 \rho_E} \left[\left(\frac{\mu_1}{\mu_{rev}} \right)^2 + \frac{6}{(k+1)(k+3)} \frac{\mu_1 \mu_2}{\mu_{rev}^2} + \frac{3}{(2k+3)(k+1)^2} \left(\frac{\mu_2}{\mu_{rev}} \right)^2 \right] \quad .. \quad .. \quad (20)$$

This equation, therefore, replaces eq. (2) in the case of an inhomogeneous distribution, and includes the correction terms required in order to obtain agreement with the observed results.

For practical calculations, eq. (20) can be rewritten in a more convenient form. Instead of having the permeability μ_1 at the centre of the lamination and $\mu_1 + \mu_2$ at the surface, we shall use the reversible permeability μ_{rev} at the centre and $\mu_{rev} + \Delta\mu$ at the lamination surface. Then, from

$$\mu_1 + \mu_2 = \mu_{rev} + \Delta\mu$$

and from eq. (13), we have

$$\mu_1 = \mu_{rev} - \Delta\mu / k \quad .. \quad .. \quad .. \quad (21)$$

$$\mu_2 = (k+1) \Delta\mu / k \quad .. \quad .. \quad (22)$$

Substituting these values in eq. (20), we obtain, after a few simple transformations, the relationship

$$\frac{1}{\mu_{PR}} = \frac{\omega d_E^2}{12 \rho_E} \left[1 - \frac{2}{k+3} \frac{\Delta\mu}{\mu_{rev}} + \frac{2}{(k+3)(2k+3)} \left(\frac{\Delta\mu}{\mu_{rev}} \right)^2 \right] = \frac{\omega d_E^2}{12 \rho_E} \eta \quad (23)$$

which is valid for all values of k. The corresponding curves for $k = 1, 2, 3, 5$ are shown in Fig. 9. This formula shows that the original eq. (2) requires an "inhomogeneity factor" η which takes account of the variation of permeability in the lamination.

The curves of Fig. 9 show, for instance, the permeability variation in a lamination for which the permeability at the surface is 1½ times greater than the

mean reversible permeability. For higher values of k, the permeability within the lamination is more uniformly distributed and closer to μ_{rev}.

When the permeability decreases from the centre outwards, $\Delta\mu$ is negative, $1/\mu_{PR}$ increases, and the effect of the eddy currents on $1/\bar{\mu}$ becomes greater as compared with the homogeneous lamination. The possible distributions are shown in Figs. 10 and 11. In Fig. 10 it is assumed that the permeability is zero at the surface of the lamination. This is obtained by putting

$$\Delta\mu = -\mu_{rev} \quad .. \quad .. \quad (24)$$

In Fig. 11 it is assumed that permeability is zero at the centre of the lamination. According to eq. (22), we then have

$$\Delta\mu = +k\mu_{rev} \quad .. \quad .. \quad (25)$$

Numerical values for η obtained by means of eq. (23) are given in Fig. 12. The curves show that the value of the factor k, which is a characteristic of the form of the inhomogeneity, does not greatly affect the overall effect of the eddy currents.

The value of the correction factor η, which, in accordance with eq. (23), is to be added to eq. (2) for inhomogeneous laminations, is

$$\eta = 12\,\rho_E/[\omega\mu_{PR}\,d_E^2] \quad .. \quad .. \quad (26)$$

and it can be determined from measured values of $1/\mu_{PR}$ when the resistivity ρ_E and the lamination thickness d_E are known. Fig. 13 shows values of this inhomogeneity factor obtained from measurements on three cores of standard lamination material No. IV of different manufactures. The mean values $\rho_E = 55$ micro-ohm cm and $d_E = 0{\cdot}35$ mm have been used in conjunction with eq. (26), since we are less interested in the absolute values than in the variation with premagnetisation. With these values we have:—

$$\frac{12\,\rho_E}{\omega\mu_0\,d_E^2} = \frac{12 \times 55}{2\pi f \times 10^3 \times 4\pi \times 10^{-9} \times 3{\cdot}5^2 \times 10^{-4}} = 6850/f\ [\text{sec/kilocycle}] \quad .. \quad .. \quad (27)$$

Thus, according to eq. (26), the inhomogeneity factor is

$$\eta = 6850\,\mu_0/(f\mu_{PR}) \quad .. \quad .. \quad (28)$$

The values of Fig. 13 are calculated from this last formula. When $H = 0$, we have $\eta = 1{\cdot}0$, corresponding to a constant permeability throughout the entire cross-section of the laminations considered.

With increasing premagnetisation the value of η either increases to 1·2 or decreases to 0·8. On the basis of Fig. 12 we can assume that $\eta = 1{\cdot}2$ corresponds to a permeability which is approximately 50 per cent lower at the surface than the mean value, while $\eta = 0{\cdot}8$ corresponds to a permeability which is 70 per cent higher at the surface of the lamination, assuming that the value of k is equal to 2 or 3.

As at frequences well above the limit frequency of the eddy currents the entire flux is displaced from the inside of the lamination to the superficial layers, the magnitude of $\bar{\mu}$ depends primarily not on μ_{rev} but on the permeability of the superficial layers only. Thus, it would be possible to measure this value independently of the variation of the eddy currents, and this could then be used as a check on the extension to the theory of eddy currents which is given in this article [3].

3. RESIDUAL LOSSES

Fig. 14 shows the values of $1/\bar{\mu}$ for a standard 4 per cent silicon-iron lamination 0·35 mm thick, for various premagnetisations. In this lamination $1/\mu_{PR}$ decreases from 1·2 to 1·0 × $10^{-3}/\mu_0$ when $f = 9$ kcps

[3] E. PETERSON and WRATHALL: *Proc. Inst. Elec. Eng.*, Vol. 24, p. 275, 1936.

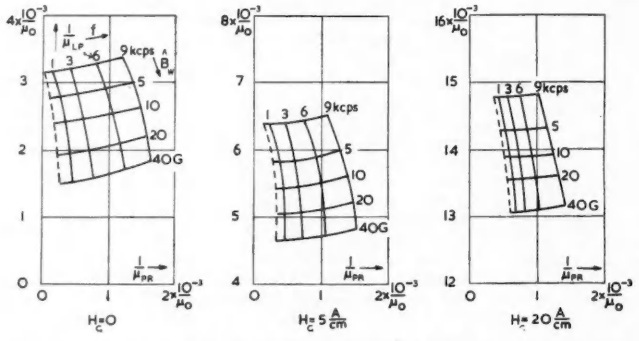


Fig. 14. **Variations of $1/\mu_{LP}$ and $1/\mu_{PR}$ for dynamo lamination No. IV, 0·35 mm thick, with appreciable residual losses occurring with increasing premagnetisation.**

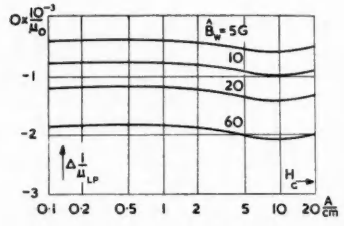


Fig. 15. **Decrease in $1/\mu_{LP}$ with different values of $\hat{B}_W$, plotted against premagnetisation.**

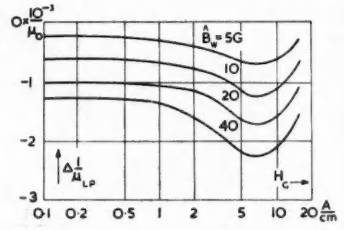


Fig. 17 (above). **Decrease in $1/\mu_{LP}$ with different values of $\hat{B}_W$, plotted against premagnetisation.**

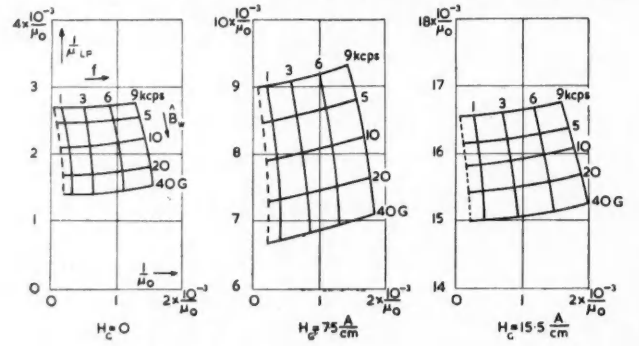


Fig. 16 (left). **Variation of $1/\mu_{LP}$ and $1/\mu_{PR}$ for dynamo lamination No. IV, 0·35 mm thick, showing considerable variation of the hysteresis effect with premagnetisation.**

and $B_W = 0$, so that this again shows the different effects of premagnetisation on reversible permeability in the inner and outer layers. This decrease of the reciprocal of the parallel-resistance permeability $1/\mu_{PR}$ is changed into a marked increase of $1/\mu_{PR}$ in the lower part of the audible frequency region. At a one-kilocycle frequency, $1/\mu_{PR}$ increases from $0{\cdot}2 \times 10^{-3}/\mu_0$ without magnetisation, to a value exceeding $0{\cdot}4 \times 10^{-3}/\mu_0$ when $H_G = 20$ A/cm. For high values of H_G, the origin of the curvilinear network, which is obtained by extrapolation for $f = 0$ and $\hat{B}_W = 0$, no longer appears to be situated on the ordinate axis. For high premagnetisation values the lamination shows residual losses which are perhaps related to the magnetic hysteresis and which normally have only a slight secondary effect in laminated cores in the audible frequency region [4]. In this regard, more accurate data could be given if the complex permeability were also known at very low frequencies. It would then be possible to see whether and to what extent the dotted extrapolation curves plotted in Fig. 14 correspond with observed values. Exploratory measurements lead one to expect that at low frequencies $1/\mu_{LP}$ decreases and $1/\mu_{PR}$ increases.

4. HYSTERESIS

Experimental evidence, as exemplified by the curves of Fig. 4, shows that the effect on $1/\hat{\mu}$ of varying the value of the alternating magnetic induction $\hat{B}_W$ is practically independent of premagnetisation. This result is also apparent in Fig. 15, in which the decrease of $1/\mu_{LP}$ at low frequencies is plotted against the premagnetisation H_G, with $\hat{B}_W$ as parameter. The effect of premagnetisation is hardly noticeable except in the vicinity of $H_G = 10$ A/cm.

Fig. 16 shows the variation of $1/\mu_{LP}$ and $1/\mu_{PR}$ for a dynamo lamination of different manufacture. The effect of $\hat{B}_W$ is particularly pronounced in the neighbourhood of $H_G = 7{\cdot}5$ A/cm. This is also visible in Fig. 17, which shows that the hysteresis effect in the region between 5 and 10 A/cm is approximately 70 per cent greater than with zero premagnetisation.

This hysteresis maximum is also observed in nickel-iron alloys. With these alloys it occurs at lower field strengths, since saturation is reached at an earlier stage. The reason why the effect is insignificant when using laminated cores in premagnetised coils and transformers is because these cores are designed with an air gap so as to avoid high constant field strengths in the laminations.

Figs. 4 and 16 also show that the angle of the dotted zero-frequency curve with the ordinate axis is not affected by premagnetisation. The angle is approximately 10 degrees for dynamo laminations, while for nickel-iron alloys it is approximately equal to 23 degrees (Rayleigh's angle) for all values of H_G used in this investigation.

[4] V. LEGG : *Bell System Technical Journal*, Vol. 15, p. 39, 1936.

BELGIUM

Electrolytic Polishing and Short-Circuit Etching of Copper and Cuprous Alloys

By M. JAROSZEWICZ-BORTNOWSKI and J. SCHOOFS. (From *Revue Universelle des Mines*, 9th Series, Vol. 5, May, 1949, pp. 170-174, 6 illustrations.)

I. A NEW POLISHING METHOD

DUE to the simplicity of the operations and the high quality of micrographs that can be obtained, the electrolytic polishing method has developed rapidly in industrial laboratories and research centres. For copper and its alloys, however, the usual electrolytic polishing process takes a long time (20 to 30 minutes in a phosphoric acid bath, 50° Bé, with the copper cathode placed horizontally above the surface to be polished) and requires careful preparation* (No. 0000 emery paper). The authors have, therefore, developed a new process. The specimen (anode) is mounted in a phosphoric acid bath, 50° Bé, so that the surface to be polished extends vertically. During polishing, the specimen is oscillated in a direction normal to the surface, the length of stroke being 60 mm (2⅜ in.), the mean distance from surface to cathode 80 mm (3⅛ in.). The copper cathode surface is very much bigger than the surface to be polished, e.g., 11 to 15 sq in. for a surface of 0·3 to 0·8 sq in. Oscillations parallel to the surface, i.e., at constant distance from the cathode, did not prove equally successful. Since the movement tends to destroy the anodic layer required for polishing, the terminal voltage must be increased. Best results were obtained with 4 to 5 volts (according to the mean position of the specimen with respect to the cathode) for a frequency of one full stroke (forth and back) per second and with 9 to 10 volts for two full strokes per second. The latter speed results in splashing of acids and is only used in special cases. Current is switched on for only 5 minutes if the specimen has been prepared with No. 00 Durex emery paper.

*P. JACQUET, *Rev. Métall.*, Vol. 35, 1938, p. 41 & 116, and Vol. 37, 1940, p. 214.

This treatment gives excellent results for the polishing of electrolytic, phosphoric, and arsenical copper, 5 per cent Mn-copper, 0·2 to 1 per cent Cd-copper, brasses with 59 to 95 per cent Cu, bronzes with ½ to 8 per cent Sn, silico-bronzes (2 per cent Sn, 1 per cent Si), Cu-Ni-Zn alloys of various compositions. Cupronickels (80/20, 75/25, 70/30) should be polished for 10 minutes in a bath of 90 per cent by volume phosphoric acid (50° Bé) and 10 per cent by volume sulphuric (60° Bé) acid. Widely differing materials can thus be treated in the same manner since the applied voltage for correct polishing can be held within wider limits if the specimen is oscillated. Results are perfect even if the surface to be polished is not treated with emery paper at all but is a plain rolled or pickled surface. Care must be taken, however, especially with brasses rich in zinc, that the surface is not structurally altered, e.g. by annealing, and appears to be richer in copper than the core of the material. In some cases (60/40 brass), a strong polishing action, 10 minutes at 9 to 10 volts with 2 full strokes per second, dissolves the affected skin metal so that correct micrographs are then obtained without emery preparation.

II. SHORT-CIRCUIT ETCHING

The electrolytically polished surface can be etched with the usual metallographic reagents. It is, however, difficult to time the etching accurately so that a good contrast and fine detail are obtained. The authors etch their specimens in the polishing bath by short-circuiting the electrodes immediately after the polishing current has been switched off and the specimen stopped at a distance of 50 mm (2 in.) from the cathode. During electrolytic polishing, a difference in concentration of

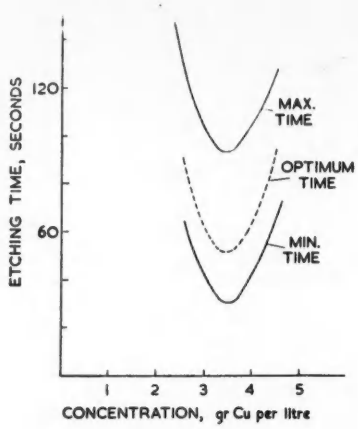


Fig. 1. **Etching time for 1 cm² (0·16 sq in.) brass as a function of the copper concentration of the electrolytic bath.**

the electrolyte is established in the neighbourhood of the electrodes and increases with the polishing time up to a limiting value depending on process conditions. An e.m.f. is created, the bath acting like a storage battery which discharges with reversed current when the electrodes are short-circuited after the polishing current has been switched off. The specimen now forms the cathode and copper is deposited on the polished surface. Since the potential difference is very small, the deposit is not uniform; its thickness depends on the grain orientation. If alpha-brass is etched in this way and examined under the microscope, some grains will appear yellow, i.e. free of copper deposit, others are deep pink, and the whole scale of colours between these extremes can be observed. Twins show distinct alternating colours except when the twinning planes are perpendicular to the polished surface, in which case a uniformly coloured surface is intersected by fine parallel lines.

The contrast clearly depends on the colour of the specimen metal and is stronger, the more this colour differs from that of copper. Brasses and Cu-Ni-Zn alloys give the clearest micrographs. For a given specimen metal, the quality of etching, i.e. intensity of contrast and simultaneous fineness of detail, depends on the quantity of copper deposited and, therefore, (a) on the short-circuiting time and (b) on the mean copper concentration of the electrolyte. For a given copper concentration, too short an etching time gives too thin a deposit and insufficient contrast; too long a time blurrs the detail. Experiments show that the optimum etching time is proportional to the size of the surface to be etched. For a given etching time, on the other hand, there is an optimum concentration, which gives sharpest contrast. A lower copper content results in too thin a deposit, and a higher content diminishes the "battery" effect of the polishing

Fig. 2. **Slide planes in a lightly worked alpha-brass, electrolytic polishing with oscillating specimen, short-circuit etching (250 ×).**

Fig. 3. **Beginning of re-crystallisation along an original grain boundary in German silver (63/12), electrolytic polishing, short-circuit etching, oblique illumination. (500 ×).**

Fig. 4. **Annealed alpha-brass, electrolytic polishing with oscillating specimen, short-circuit etching. (500 ×).**

electrolysis and, hence, the short-circuit current and the quantity of deposit. The contrast again becomes insufficient (see Fig. 1). The shortest etching time is obtained with a concentration of about 3·5 gr Cu per litre (0·56 oz per gal) and the authors, therefore, always dissolve 1·12 oz copper carbonate per gal. of the bath. This addition does not interfere with the polishing action, and the copper content changes very little during use. It can be adjusted by the addition of fresh acid or by weak electrolysis with a graphite anode.

Short-circuit etching can also be applied if the specimen is not oscillated during polishing; the etching times should then be slightly longer. With oscillation speeds of 2 full strokes per second, however, the gradient of concentration is not sufficient for satisfactory short-circuit etching. Attention is finally drawn to the fact that ingot segregations influence the speed of metal dissolution in all electrolytic polishing processes. Raw ingot material is, therefore, not suitable for the electrolytic etching process.

FRANCE

Apparatus for Continuous Measurement of the Calorific Value of Fluids

By P. SCHULLER. (From *Chaleur et Industrie*, Vol. 30, No. 286, May, 1949, pp. 112-114, 2 illustrations.)

CONTINUOUS measurement and automatic control of the heating power of a continuous supply of liquid or gaseous fuel are important to many industries, whether it is a question of the control of a heating system, the establishment of optimum conditions, or the determination of heat supplied to a consumer. Measurement is usually made of the volume of flow, the calorific value, and the specific weight, but these measurements must be taken singly and discontinuously, and entail a fair amount of calculation. Fig. 1 shows a new patented apparatus, which allows of continuous measurement, does not necessitate any calculations, and can be adapted for automatic control. C is the measuring pipe for the combustion fluid and contains orifice D. Instead of a pressure gauge as would be used for determination of the volume of flow, there is arranged in parallel with the orifice D a calorimeter J preceded by an orifice d. Since flow through the calorimeter is very small, pipe losses can be neglected and the loss of head across orifice d is then the same as that across D. The calorific value of the gas burnt in the calorimeter is

$$c = A \times \Delta T/q = A \times \Delta T/k\sqrt{H},$$

where A = constant quantity of water flowing through the calorimeter, ΔT = difference in temperature of inflowing and outflowing water, q = volume of combustion fluid passing through the calorimeter, k = a constant depending on physical characteristics of orifice d, and H = loss of head across d or D. The total heating power of fluid passing through pipe C is, therefore,

$$\phi = Q \times c = \frac{K\sqrt{H}A\,\Delta T}{k\sqrt{H}} = \frac{K}{k} A\,\Delta T,$$

where Q = volume of combustion fluid passing through pipe C, K = a constant depending on physical characteristics of orifice D. Since k, K, and A are kept constant, the difference in water temperatures as read from the thermometers of the calorimeter is directly proportional to the heating power.

Since pressure in the calorimeter is the same as that in pipe C, air must be supplied under pressure. A large amount of excess air is supplied so that variations in the excess air ratio do not influence the measurement of the calorific value to any appreciable extent. Air is compressed to a pressure slightly above that of the fluid before orifice D and is blown into pipe C and the calorimeter through pipes a and b, which are interconnected. An orifice d_1 is arranged in pipe b, just before entry into the calorimeter. The pipes a and b are then under the same pressure as the gas in pipe C and the loss of head across d_1 is the same as that across D or d. The amount of air supplied to the calorimeter, therefore, varies with this loss of head, i.e., in similar ratio to the amount of gas supplied. Excess air above this amount escapes into pipe C. Complete combustion is thus guaranteed and the excess air ratio does not become too large even if the flow of gas is very small. One disadvantage of this apparatus is that air and gas which has undergone combustion are introduced into pipe C, but the total amount is only about 35 cubic feet per hour and, therefore, is negligible in industrial installations with a flow of gas of more than 7000 cu ft per hour.

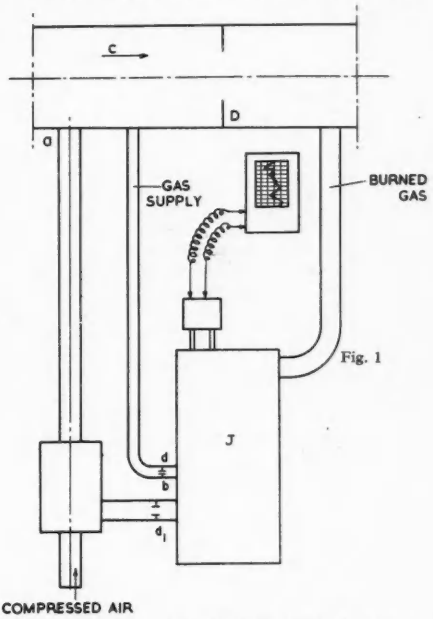


Fig. 1

Ignition difficulties have been solved by the use of a sparking plug and a magneto. The apparatus can be used under the most difficult circumstances, such as pulsating flow, variations in the composition and specific weight of gas, and sudden variations of flow. It has been used for gas flow with changes in the calorific value from 4000 to 6500 cal. The precision of this apparatus was checked by the usual methods of discontinuous measurement and showed a maximum error of less than 5 per cent. Measurements are very rapid, and variations of calorific value are registered in less than 30 seconds. If the calorimeter is replaced by a heat exchanger, the arrangement can be used for the measurement of the flow of heat in heated air or liquid. Adaptation for automatic control is simple. The temperature difference ΔT can be kept constant by automatic electric control of a valve which regulates the fluid volume passing through pipe C.

The Detection of Inter-Turn Faults during Impulse Tests of Transformers

By H. AESCHLIMANN. (From *Bulletin Sécheron*, No. 20D, 1948, pp. 13-23, 20 illustrations.)

INTRODUCTION

IMPULSE testing of transformers is of real advantage only if methods are known by which temporary inter-turn faults, or spark-overs, of short duration occurring during the tests can be detected. It might be assumed that such faults would initiate permanent 50 cps short-circuits as soon as the normal 50 cps voltage is induced. In practice, however, this is not always the case, not even if the surge voltage is applied when the 50 cps voltage is just at its peak value. In oil transformers, impulses can produce faults of very short duration, which disappear again after only a small fraction of a half-cycle of the 50 cps supply. As regulations in many countries stipulate that acceptance type tests of transformers must include impulse tests, experiments were carried out with cathode-ray oscillographs, on models as well as on complete transformers, in order to develop a method by which such internal faults in transformer windings could be detected with certainty. The method found to be most promising consisted essentially in recording electrical phenomena taking place in a transformer winding when impulse tests are made at a reduced voltage and to compare these records with corresponding records taken during the full-voltage tests.

The experiments were carried out on a three-phase transformer with the following characteristic data: rated capacity 250 kVA, primary voltage 20,000 V $\pm$ 4%, secondary voltage (no-load) 400/231 V, primary current 7·22 A, secondary current 361 A, number of h.v. turns per phase 1801.

MEASUREMENTS

The following three series of experiments were carried out:

(a) *Basic experiments.* To obtain a satisfactory understanding of the phenomena occurring when a steep-front wave is applied to the winding, all windings except one h.v. winding were removed from the transformer. This ensured that the phenomena were not influenced by other windings. The one remaining winding was subject to h.v. impulses which were below the value liable to damage the winding. The winding was provided with taps which were connected to corresponding spark-gaps submerged in oil, by means of which spark-overs could be obtained as and where required. Basing our considerations on the fact that on the occurrence of a short-circuit between turns, the part which has been suddenly short-circuited will initiate an electrical oscillation, the tank was mounted on insulators and connected to earth through a shunt. The end of the coil could be either connected to the tank or left free. This arrangement made it possible to observe the oscillations produced. Experiments were carried out, for instance, with the spark gap in parallel with the first five turns. Oscillogram Fig. 1 shows the earth current with and without spark-over for this arrangement. Similar measurements were made for various numbers of turns short-circuited solidly or through spark gaps.

The approximate actual location of the spark-over in a coil can be determined from the position of the high-frequency oscillation appearing in the oscillogram and the known speed of propagation of the electric wave in the conductor.

(b) *Measuring the electrical oscillations in the winding.* The rapid suppression of the magnetic flux when a coil or part of a coil is short-circuited is bound to affect the natural frequency of a transformer coil. Experiments to investigate this change were carried out on the same transformer as was used in the experiments described under (a); in this case also, all but one h.v. winding had been removed. The arrangement is shown in Fig. 2; the winding is earthed through a condenser.

Where the winding is not accessible, the natural frequency of the coil can be shown indirectly by insulating the tank from earth and by measuring the voltage induced in the tank, which, of course, is capacitively linked with the coil. An example of the arrangement with a corresponding oscillogram is shown in Fig. 3.

It was found that under normal conditions the natural frequency of the coil was 10^3 cps; when a solid short-circuit, or a spark-over between the 9th and the 10th tap of the coil was produced, the natural frequency of the coil increased to 10^4 cps. The change of natural frequency is, therefore, very pronounced; this can best be seen from Fig. 3, where point (a) marks the instant when the spark-over ceases. That there is a different frequency before and after this point is very obvious, and similar changes were observed in all experiments which involve spark-overs.

It was found that the actual location of the spark-over or the short-circuit had but a small influence on the magnitude of the change in the natural frequency. Moreover, the relative number of short-circuited turns has, up to a certain limit, only a minor influence, and experiments showed that the short-circuiting of one

Fig. 1. **Impulse test with and without spark-over on spark-gap across 5 turns.**

1 Impulse voltage
2 current in shunt (no spark-over)
3 current in shunt (spark-over across 5 turns).

Fig. 2. **Oscillations during impulse test, the 9th and 10th, tap being solidly short-circuited.**

1 Impulse voltage
2 Oscillations on the free end of the coil, the 9th and 10th tap not being short-circuited
3 oscillations on the free end of the coil, the 9th and 10th tap being solidly short-circuited.

Fig. 3. **Oscillogram of potential induced in tank (with and without short-circuit). The tank is insulated and connected to earth over a condenser.**

1 Potential when no short-circuit occurs
2 potential when 9th and 10th tap are solidly short-circuited
3 potential when spark-over occurs between 9th and 10th tap; ceases at point (a).

Fig. 4. **Oscillogram during impulse test with second winding (not subject to impulse) in place.**

1 Impulse voltage
2 potential between tank and earth when there is no short-circuit
3 potential betwen tank and earth when the 9th and 10th taps are temporarily short-circuited by spark-over.

Fig. 5. **Impulse voltage applied to one phase; solid short-circuit; neutral insulated.**

1 Impulse voltage
2 potential between insulated tank and earth; no short-circuit in winding
3 as (2), but 5 turns (3 per cent of total number of turns per phase) solidly short-circuited.

Fig. 6. **As Fig. 5, but temporary short-circuit by spark-over instead of solid short-circuit.**

Fig. 7. **Oscillogram of voltage induced in tank; extension of time by back-sweep of beam at reduced uniform speed.**

1 Impulse voltage
2 induced voltage (no short-circuit occurs).

Fig. 8. **As Fig. 7, but with solid short-circuit across 5 turns.**

Fig. 9. **Impulse test with neutral connected to tank and temporary short-circuit of 5 turns through spark-over.**

1 Impulse voltage
2 potential when no short-circuit occurs
3 potential when spark-over occurs.

NOTE:—In all illustrations, cuve = tank, and OC = cathode-ray oscillograph.

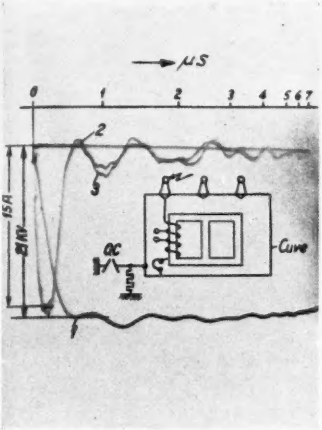


Fig. 1.

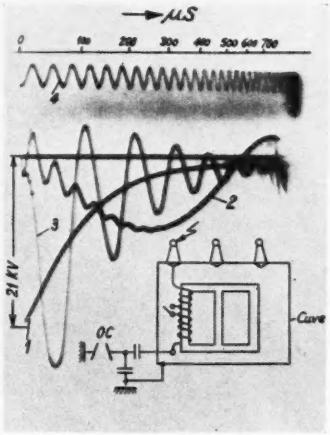


Fig. 2.

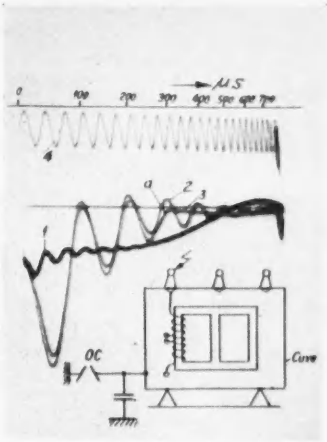


Fig. 3.

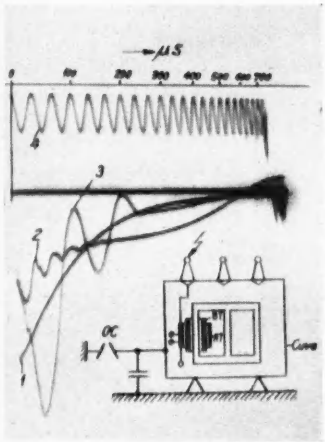


Fig. 4.

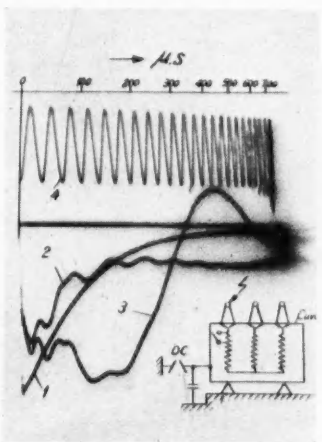


Fig. 5.

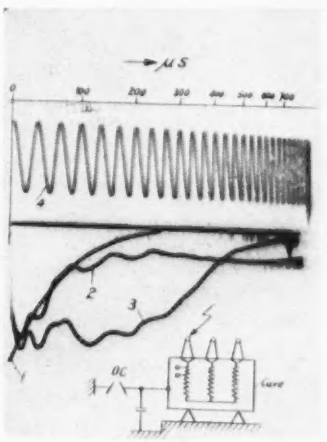


Fig. 6.

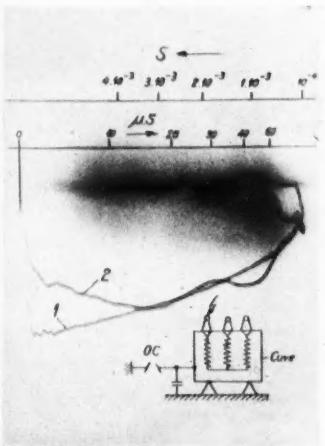


Fig. 7

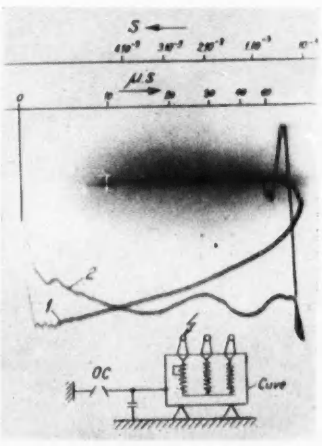


Fig. 8.

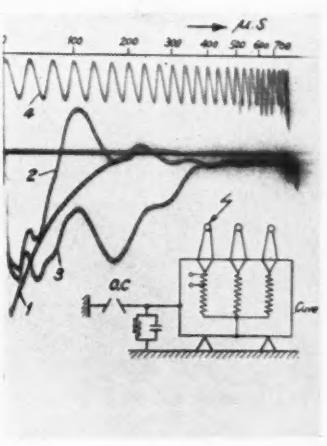


Fig. 9.

single turn (in this case amounting to only 5 per cent of the coil) produces changes of frequency as obvious as those shown in Fig. 3.

Similar experiments were carried out with the low-voltage winding in place (Fig. 4), the spark gaps being connected to the l.v. winding, and three h.v. windings being connected in parallel. Except for this latter connection, the commencement and the cessation of the spark-over could be clearly noticed in every case.

(c) *Experiments on the complete transformer.* It was found that useful results were obtained only if the individual phases were tested separately. The recording of the voltage induced in the tank proved adequate also for the complete transformer, and specimen oscillograms are shown in Figs. 5 and 6. It was found interesting to extend the period of recording from about 10^{-3} seconds to 4 $\times$ 10^{-3} seconds, and for this purpose the beam of the cathode ray tube—after completing its sweep from left to right—was made to sweep from right to left, but at a reduced and uniform speed. Two oscillograms taken with this arrangement are shown in Figs. 7 and 8, which show up more clearly the difference between the two natural frequencies.

If the neutral point of the winding is directly connected to the tank, the arrangement shown in Fig. 9 can be successfully used to detect temporary or permanent faults. From Fig. 9 it can also be seen that the spark-over ceased after 300-400 μs (micro-seconds).

The oscillations can also be measured on one of the terminals of a coil not directly connected to the impulse generator. Experiments have shown that the shape of the voltage on such a terminal also shows a considerable difference, whether or not an internal short-circuit exists. In this case the tank can be directly earthed. One terminal of each of the coils not connected to the impulse generator should be connected to earth.

In conclusion, it should be mentioned that the method described is now being used for experiments on prototypes and models.

HUNGARY

Three-to-two Phase, Artificially Cooled Dry Transformer as Power Supply for Thermo-Electric Use

By J. LISKA. (From *Elektrotechnika*, Vol. 41, No. 5, May, 1949, pp. 128-131, 8 illustrations.)

A TRANSFORMER was required in Hungary to supply 60,000 A, two-phase, 50 cycles at 2 $\times$ 10 V, i.e., a power of 1200 kVA, for thermo-electric use. Regulation of the voltage down to 4 V in 15 steps was specified, with continuous regulation between two neighbouring steps during service. The available power was a 50 cycle, three-phase supply at 10,000 V.

1. *Voltage Regulation.*

It was not considered advantageous to carry out the voltage regulation on the three-to-two phase transformer. A second transformer with a transformation ratio of 10,000/500 V was used for this purpose ; its primary can be star- or delta-connected, and the secondary can be connected in varying parallel or series combinations.

The step-changing switch is immersed in oil inside the tank, but is operated from outside. The no-load voltage is regulated in steps of 7·5 per cent, the voltage of the secondary of the transformer varies between 200 and 533 V, and the voltage of the three-to-two phase transformer varies between 3·75 and 10 V.

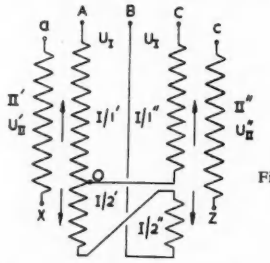


Fig. 1.

An induction regulator, which is included in the secondary circuit of the 10,000/500 V transformer, serves the purpose of continuous voltage regulations between two neighbouring steps.

2. *Design of the Three-to-two Phase Transformer.*

Considering the high current intensities required, it was preferable to choose a type of transformer having windings on two cores only. The two windings had to be identical, and it was required that unsymmetrical loading should not cause additional stray losses.

The transformer in Fig. 1 satisfies these conditions. There are no additional stray losses in the case of unsymmetrical loading, as the primary current on the unloaded core divides in the oppositely wound coils in inverse proportion to the number of turns. 5·75 per cent more material is required for the windings of this transformer than in the case of a three- or two-phase transformer of equal power.

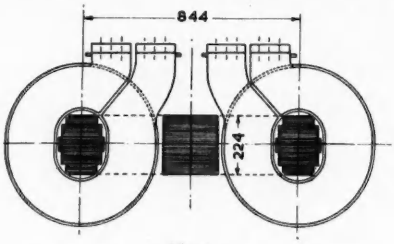


Fig. 2.

The transformer is installed in a pit under the machine it supplies and the connecting bars are as short as possible. The secondary winding is of the water-cooled tubular type. The primary windings are

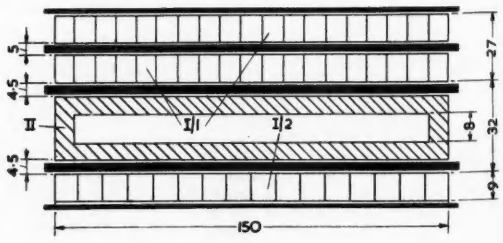


Fig. 3.

disposed between the secondary windings and, therefore, are indirectly cooled. The heat evolved in the core is dissipated by the artificial ventilation of the pit. No oil is used for cooling or insulation.

Fig. 2 shows a cross-section of the core, which lies horizontally.

The coils are disc-shaped. The primary and secondary windings each consist of eight parallel-connected coils. The cross-section of a coil group is shown in Fig. 3, II being a secondary coil and I/1 and I/2 primary coils. Bakelite distance pieces of $\frac{3}{32}$ in. thickness are interposed between neighbouring coil groups.

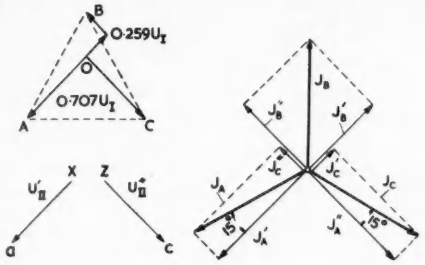


Fig. 4.

Representing the line voltage as U_I, the winding I/1 was designed for the voltage $U_I/\sqrt{2} = 0{\cdot}707\ U_I$ and the winding 1/2 for the voltage $(\sqrt{3/8} - \sqrt{1/8})\ U_I = 0{\cdot}259\ U_I$ (see Fig. 4). The number of turns in the coil I/1 is 38 and that in the coil I/2 is 14.

3. *Stray Reactance.*

The stray reactance was calculated from the summation of the short-circuit losses of single-phase measurements. As shown in Fig. 5, the winding II′ was first short-circuited and the primary connected to *A* and to *B* and *C* connected in parallel ; the winding II″ was then short-circuited and the primary connected to *C* and parallel-connected *A* and *B*. As the design is symmetrical, the two measurements were identical.

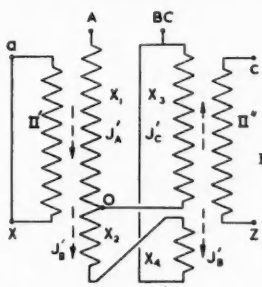


Fig. 5.

The reactance in relation to the winding II′ can be considered as consisting of four parts : X_1 the reactance in the winding N_{I1}, X_2 the reactance in the winding N_{I2} when the secondary 11′ is short circuited, and X_3 and X_4 the reactances of the windings N_{I1} and N_{I2} on the core *C* when they are connected in opposition. The reactance X_3 is in parallel with $X_2 + X_4$.

To calculate X_1 and X_2, the secondary tubular conductor is assumed to consist of two parallel bars, as shown schematically in the cross-section of a coil group in Fig. 6. The distribution of the induction is also shown. Representing the average length of a turn as l_k and the frequency as f, the reactance components can be calculated from the following formulae :

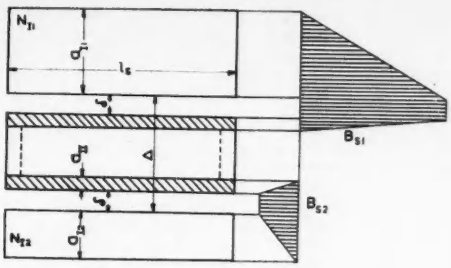


Fig. 6.

$$X_1 = 1{\cdot}256 \times 2\pi f N_{I1}^2 \frac{l_k}{l_s}\left(\delta + \frac{Q_{I1} + Q_{II}}{3}\right) \times 10^{-8}$$

$$X_2 = 1{\cdot}256 \times 2\pi f N_{I2}^2 \frac{l_k}{l_s}\left(\delta + \frac{Q_{I2} + Q_{II}}{3}\right) \times 10^{-8}$$

$$X_3 = 1{\cdot}256 \times 2\pi f N_{I1}^2 \frac{l_k}{l_s}\left(\frac{\Delta}{2} + \frac{Q_{I1}}{3}\right) \times 10^{-8}$$

$$X_4 = 1{\cdot}256 \times 2\pi f N_{I2}^2 \frac{l_k}{l_s}\left(\frac{\Delta}{2} + \frac{Q_{I2}}{3}\right) \times 10^{-8}$$

Replacing the dimensions of the transformer : $l_k = 133$ cm, $l_s = 15$ cm, $\delta = 0{\cdot}45$ cm, $a_{I1} = 2{\cdot}7$ cm, $a_{I2} = 0{\cdot}9$ cm, $a_{II} = 0{\cdot}8$ cm, and $\Delta = 3{\cdot}2$ cm, the calculated reactances are : $X_1 = 0{\cdot}083$, $X_2 = 0{\cdot}0071$, $X_3 = 0{\cdot}128$ and $X_4 = 0{\cdot}013$. The currents flowing in the three phases of the primary during the single-phase short-circuit measurements were :

$$I_A' = 156 \text{ A}, I_B' = 114 \text{ A and } I_C' = 42 \text{ A},$$

and the corresponding voltage drops in the reactances were calculated to be

$$X_1 I_A' = 0{\cdot}083 \times 156 = 13 \text{ V},$$

$$X_3 I_C' = 0{\cdot}128 \times 42 = 5{\cdot}4 \text{ V, and}$$

$$(X_2 + X_4) I_B' = (0{\cdot}0071 + 0{\cdot}013) \times 114 = 2{\cdot}28 \text{ V}.$$

The voltage values calculated for the two parallel branches were unequal, but this means that the current does not divide in the two branches, as would be the case if the stray reactances could be neglected. In fact, I_C' is somewhat larger and I_B' smaller ; calculations show that these differences are small and the voltage drop in the parallel branches is 3·12 V.

The reactance voltage on the primary side is calculated as

$$U_S = 13 + 3{\cdot}12 = 16{\cdot}12 \text{ V, or}$$

$$\frac{100\ U_S}{0{\cdot}966\ U_I} = \frac{16{\cdot}12}{515}\ 100 = 3{\cdot}13 \text{ per cent of the full voltage.}$$

The measured value was 10 per cent larger, which can partly be explained by the reactance of the short-circuiting bars.

4. *Losses.*

The current densities in the three windings are 1610, 1660 and 2190 A/sq in. respectively. The additional a.c. losses in the coil I/1 amounted to 3·6 per cent and those in the coil I/2 to 2·5 per cent. The total copper losses are 2·83 per cent of the full-load power of the transformer and the no-load losses are 1·7 per cent, the maximum induction being 12,000—12,600 Gauss.

5. *Cooling.*

Assuming an 18° F increase in temperature of the cooling water and cooling air, the quantity of water

necessary is 104 cu ft/hour and the quantity of air 405 cu ft/min. The core dissipates 0·64 W/sq in. and its temperature increase is less than 90° F.

Calculations show that the warmest part between the windings is between the coils I/1 and II, the temperature increase being 131° F at full load. The cooling water inside the secondary coils will be a further 9° F warmer. Assuming that the temperature of the cooling water is 77° F, then the temperature of the warmest point of the transformer is 217° F, which is permissible. This calculation did not take into account the influence of the cooling air, and conditions in the transformer are, therefore, more favourable than is represented by the above figures.

Effects of High Temperatures of Short Duration on Paper and Cotton Insulation

By A. V. KORITSKY. (From *Vestnik Elektropromyshlennosti, Russia*, No. 12, 1948, pp. 20-22, 2 illustrations).

WHILE the behaviour of paper and cotton insulation subjected to elevated temperatures over long intervals has been fairly well explored, a similar investigation for very high temperatures of momentary duration has been carried out for the first time. The temperatures in question were of the order of 250° C and more, and occur in practice under short-circuit conditions. The duration of the high temperature application varied, but did not exceed 10 seconds at a time.

Brass tubes of 18 to 20 mm diameter and 60 mm length were used as indicators, on which measuring resistances of enamelled copper wire were wound. On this winding was superimposed a heating winding, which was covered with several layers of thin press-board.

For the purpose of the investigation, the heating coils were fed from current transformers connected in the output leads of a power transformer. The nominal current density in the heating coils was selected at 10 amp/mm², and overloads of short duration were applied, thus simulating short-circuit conditions, and insulating paper was placed inside the heating coils.

Currents of different duration and intensity were applied, the time being measured to within 0·05-0·1 sec. The experiments were carried out in an oil tank, which was maintained at 89 to 91° C. Table I gives the results of the experiments. The applications of current were interrupted by 10 minute intervals to allow the spools to cool off.

TABLE 1.

No. of sample	Current intensity amp/mm²	Duration seconds	Number of applications	Temperature °C of the spool	Observations
1	96	4	1	310	Slight smoke before switch-off
2	76	8	1	310	Smoke in the 5th second
3	76	4	25	205	No smoke, ebullition of oil
4	74	8	25	310	At first, slight smoke; at the 9th, switching smoke
5	126	2	25	280	At first few applications, slight smoke
6	116	4	1	500	Dense smoke clouds
7	124	3	1	400	Smoke clouds
8	51	17	50	325	At first, slight smoke
9	82	10	1	450	Smoke clouds
10	75	9	1	340	Smoke

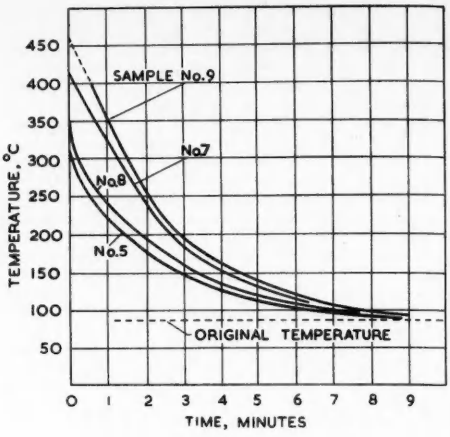


Fig. 1.

Curves showing the cooling-off process are seen in Fig. 1 for several of the test samples.

After the test, the insulation under investigation was examined for outward appearance and subjected to micro-analysis.

Table 2 gives the results of micro-analysis of some of the samples, the classification being as follows :

1. New Insulation, fibres undamaged.
2. Condition very good, less than 5 per cent damaged fibres.
3. Condition satisfactory, less than 75 per cent damaged fibres.
4. Condition of insulation unreliable, over 75 per cent fibres damaged.
5. Nearly all fibres damaged.

TABLE 2.

No. of Sample	Description	Condition
2	Paper	3
3	Cotton Cotton inner layers	2 3
4	Paper	5
5	Fastening tape, light spots Fastening tape, dark spots Cotton outer layers Cotton inner layers	2 3 3 5
6	Paper	5
7	Cotton outer layers Cotton, first layers	4 3
8	Cotton inner layers Paper Cotton outer layers	5 5 3
9	Cotton, outer layers	5
10	Cotton outer layers Cotton inner layers	2 3

The outward appearance varied from only slight discoloration with no loss of insulation properties in sample 1, to carbonizing in samples 5, 8 and 9.

The results of the investigation demonstrate that paper and cotton insulation can withstand single impulses, raising the temperature to 300° C. When the number of impulses is large, the limit of temperature should not exceed 200-225° C.

Present Status of the Development of Hand-Fired Smokeless Coal Heaters

By J. R. FELLOWS.* (From *University of Illinois Bulletin*, Vol. 46, No. 79, July 1949, pp. 38-58, 9 illustrations.)

Illinois Smokeless Furnace—First Design.

Although several preliminary experimental furnaces were designed, constructed, tested, and then discarded, the furnace which will be referred to in this paper as the " first design " is the first specific arrangement of parts that was actually used for heating a residence. Fig. 1 shows a vertical sectional view of this arrangement. The fuel bed is shown in the condition which would exist immediately after the placing of a charge of fresh coal. The baffle wall, the vertical secondary air passages, and the combustion flues are formed by special refractory units, a detail of which is shown in Fig. 2. Each baffle wall unit or section is composed of two matching E-shaped bricks which, when in position, are supported at the bottom by the firepot lining and at the top by two horizontal metal plates which form the secondary air passage. The inside width of the furnace is determined by the number of baffle wall sections required.

Each charge of fresh coal is converted to coke in the coking chamber at the front of the furnace while that converted from the previous charge is burned in the coke-burning chamber at the rear. The volatile matter released as a gas from the fresh coal mixes with the secondary air introduced through the vertical air passages adjacent to the combustion flue. The mixture passes over live coals in the coke-burning chamber, where it is ignited. The burning is then completed in the combustion flues.

The rate of release of gases from the fresh coal is governed by the amount of air admitted to the coking chamber, and the rate at which the coke is burned is determined by the amount of air passing into the ashpit and through the grates. The orifice in the firing door and the one in the ashpit door are so proportioned that each charge of fresh coal is converted to coke before that from the previous charge is completely burned.[1]

A series of tests was conducted in the laboratory to determine the burning characteristics of a wide variety of solid fuels. The furnace used in this test included 3 of the baffle wall sections illustrated in Fig. 2. The coal samples, weighing from 200 to 400 lb differed widely with respect to such properties as moisture content, volatile matter content, ash content, ash fusion temperature and friability of coke formed.

The following general conclusions, based on the experience obtained in the laboratory tests, may be drawn with respect to the burning characteristics obtained with different solid fuels :

(a) Fuels having a range of volatile matter content of from 1·5 per cent to 41·9 per cent were satisfactorily burned.

(b) Coals having a high ash content introduced no difficulty apart from the inconvenience of removing greater amounts of ash. From the standpoint of hold-fire characteristics, in fuels having a high ash content the ash served to insulate a small bed of hot coals and thereby tended to increase the possible length of the hold-fire period.

(c) Bituminous coals having ash-softening temperatures ranging from about 1900 to 2800° F were burned without formation of slag or clinkers.

(d) Coals ranging in size from $\frac{1}{4}$ in. by $\frac{3}{4}$ in. to 3 in. by 6 in. were satisfactorily burned. However, it was found that strongly coking coals did not coke thoroughly in the centre of the charge if a large proportion of the pieces was less than 2 in. in diameter.

A 3-section furnace practically identical with the one used for the laboratory tests was installed in a Warm Air Heating Research Residence[2] in the fall of 1943, and in March 1944 replaced by a 4-section unit of the same type. The larger furnace was tested during the rest of

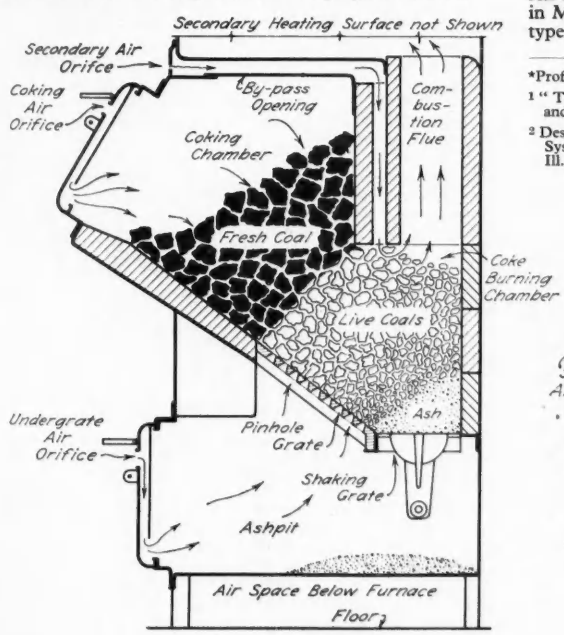


Fig. 1. **Cross-section of first design.**

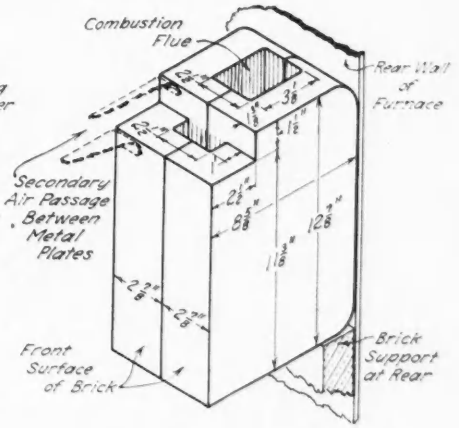

Combustion Flue
Rear Wall of Furnace
Secondary Air Passage Between Metal Plates
Front Surface of Brick
Brick Support at Rear

Fig. 2. **Detail of refractory unit.**

*Professor of Mechanical Engineering, University of Illinois.

[1] " The Illinois Smokeless Furnace," by J. R. Fellows, A. P. Kratz, and S. Konzo, 1947.

[2] Described in " Investigation of Warm Air Furnaces and Heating Systems," by A. C. Willard, A. P. Kratz and V. S. Day, Univ. of Ill. Eng. Exp. Sta. Bul. 189.

the spring of 1944 and throughout the entire 1944-45 heating season.

Throughout the test period continuous records were made each day of the CO_2 content and temperature of the flue gases at the smoke collar of the furnace. Both the percentage of CO_2 and the temperature of the flue gases increased as the weather became colder, and for a given indoor-outdoor temperature difference, the CO_2 content and the flue gas temperature were both greater for the 3-section furnace than for the 4-section, the latter being equipped with a greater heating surface. Hence for a given hourly fuel consumption a greater transfer of heat occurred from the flue gas to the circulating air, and as a result lower flue gas temperatures were obtained. The slightly lower CO_2 values recorded on the larger furnace probably resulted from the fact that a proportionally larger amount of secondary air was supplied during off-period operation. Also, the larger furnace operated with longer periods of closed dampers than did the smaller.

The losses due to sensible heat and water vapour in the flue gases at the smoke collar were practically constant over a wide range of indoor-outdoor temperature differences, and amounted to approximately 21 per cent for the 3-section furnace and 16 per cent for the 4-section. These losses, expressed as a percentage of the heat liberated in the furnace, did not include losses resulting from unburned combustible in the ash and refuse. The latter amounted to about 5·5 per cent of the heat liberated for the 3-section furnace and about 4·6 per cent for the 4-section. Hence the total losses, including those due to sensible heat and water vapour in the flue gases and to combustible in the ashpit, were about 26·5 per cent and 21 per cent respectively for the 3-section and 4-section units. The corresponding combustion efficiencies, defined as 100 minus the total losses, were about 73·5 and 79 per cent respectively.

Although this type of furnace performed satisfactorily in the Research Residence and in many private homes, there was in every case a noticeable loss of coke through the grate and it was difficult to transfer the newly formed coke from the coking chamber to the coke-burning chamber when burning a strongly coking type of coal during extremely cold weather.

Second Design.

Fig. 3 is a sectionalised view showing the interior construction of the second design and Fig. 4 is a vertical cross-sectional view showing the various parts of the furnace in their proper positions in the complete assembly.

The second design incorporates the downdraught coking principle of smokeless combustion that was used in the first design. A round body has been substituted for the square one, the inclined pinhole grate has been eliminated, the shaking grate has been expanded so as to extend under the entire firepot, and the baffle wall has been simplified. The secondary air is brought into the furnace through a tube extending through the casing from the back of the firepot, from which it passes into the perforated channel, then through the holes in the channel into the mixing space directly below the combustion flue. The primary undergrate air enters the perforated channel along with the secondary air, but from that point it passes through the metering slots in the edge of the grate ring at the base of the channel, into the ashpit. The secondary air and the undergrate air are properly proportioned because the total area of the holes in the channel bears the correct relationship to the total area of the slots in the grate ring. The coking air which supports the combustion in the fresh fuel and causes the volatile matter to be gasified is handled in essentially the same way as in the earlier design.

The only fundamental change is in the manner in which the secondary air and the primary undergrate air are metered and delivered to their respective points of

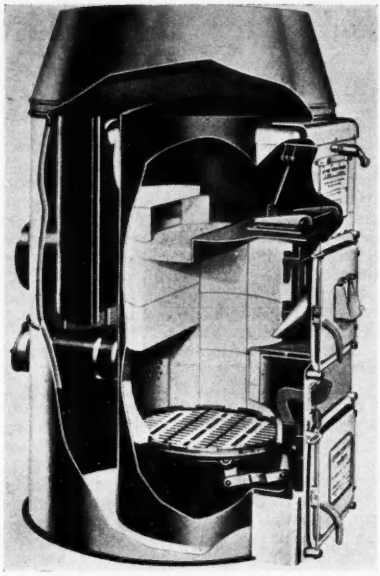


Fig. 3. **Sectionalised view—Interior construction of the second design.**

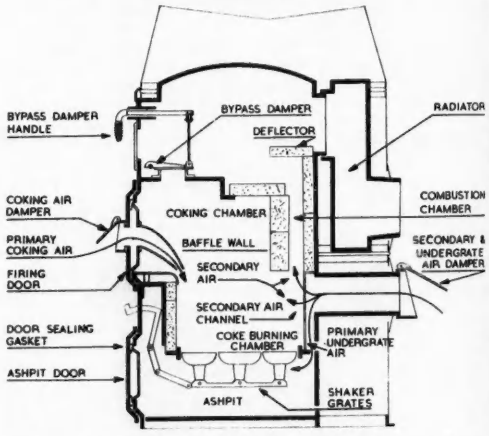


Fig. 4. **Vertical cross-sectional view of complete assembly.**

usage. It was expected that the revised furnace would operate in a manner practically identical with that of the earlier design. The advantages in the revised construction consist of decreased manufacturing cost, better grate efficiency, and simplified firing technique.

Operating Principle.

Smokeless combustion is achieved by placing the fresh coal in a separate coking chamber, where the rate of gas release can be controlled, leading the released gases and the secondary air to a mixing chamber, and providing an ignition surface in the mixing chamber in the form of burning coke. Smokeless combustion is achieved in the underfeed stoker by feeding the raw coal into a small coking zone as needed, blowing air into this same zone, and providing a layer of burning coke directly above the point where the gas and air are mixed.

Special Test of Second Design.

A special test of the new type of smokeless furnace was conducted by the writer in the Mechanical Engineering Laboratory at the University of Illinois for the purpose of obtaining data of interest to those engaged in smoke abatement work.

The coal burned was a high-volatile bituminous type of nut size in which the lumps ranged from 1½ to 2 in. in diameter. The smoke density was measured and recorded by means of an instrument which utilizes the principle of a beam of light projected across the smoke pipe onto a thermopile located on the opposite side. The draught was regulated by means of an adjustable cross-damper instead of the automatic balanced damper normally employed, in order that there might be no dilution of the products of combustion before they passed the station at which the smoke density was measured.

The test extended over a period of approximately 100 hr. Bituminous coal was burned at combustion rates which ranged from the highest obtainable to the lowest that can be maintained without losing ignition in the lower fuel bed. The smoke recorder was placed in operation and the zero reading adjusted before the fire was kindled, and was maintained in operation throughout the test. Analyses of the flue gas to determine the percentage of CO_2 were made at frequent intervals (5 to 30 min). Each time that an analysis of the flue gas was made, the flue gas temperature, draught, and smoke density were also recorded.

The test period in which the maximum possible burning rate was maintained followed the starting cycle, after which the combustion rate was reduced in each succeeding cycle until absolute minimum had been reached. The periods between firings ranged from 5 hr at the maximum burning rate to 24 hr at the medium and lower rates.

Comparison of Smoke Records with Those from an Underfeed Stoker.

Since smoke density is very difficult to measure on an accurate quantitative basis, it seems logical to compare the performance of the new furnace with that of a stoker-operated furnace under similar conditions as to burning rate and when burning coal produced by the same mine.

Test results show that considerably more smoke was produced by the stoker-fired furnace than by the smokeless furnace under the conditions of high-rate burning. There was little difference in the amount of smoke produced by the two devices at moderate burning rates.

The peaks in a smoke record from an underfeed stoker result when the fan and feedscrew are stopped after a period of operation. The momentary smoke production is caused by a shortage of secondary air, and the conditions are quite similar to those occurring in the hand-fired smokeless furnace when the dampers are abruptly changed from a wide-open position to one that is completely closed. In the case of the stoker, fresh fuel is continuously fed into the coking zone while the mechanism is in operation. The longer the period of operation, the greater is the rate of gas release at the time the fan is stopped and the longer will be the time interval during which there is a shortage of secondary air. It would therefore be expected that more frequent and more dense smoke emissions would occur in colder weather, and this is indicated by the cold weather and moderate weather records.

Extremely low-rate burning was thoroughly investigated in the case of the smokeless furnace, as it is under this condition that the amount of smoke produced is most affected by the exact condition of the fuel bed at the time of firing and by the technique used by the operator. During moderate winter weather and during cold weather the best possible results may be achieved by applying a standard procedure (shake grate, poke down coke, and fill coking chamber) once or twice each 24 hr. The thermostat, through operation of the damper motor, will maintain a uniform room temperature at all times. The writer can see no reason why results comparable to those obtained for high and medium burning rates will not be duplicated in a home equipped with a furnace of this type during weather which requires burning rates in those ranges. However, in early fall and in late spring, when the outdoor temperature at any time may rise to 70° F or above, it is necessary to leave a bed of ash on the forward part of the grate to prevent occasional over-heating. The correct procedure in firing the smokeless furnace under these conditions of operation is to poke the ashes through the grate at the back of the firepot, push all available coke back against the air channel, and place a small charge of coal in front of the coke. The results of the tests clearly indicate that if this procedure is followed, little smoke will be produced and good results will be achieved regardless of whether the previous charge is completely coked and hot, completely coked and nearly " dead," or only partly coked and nearly " dead," at the time of firing.

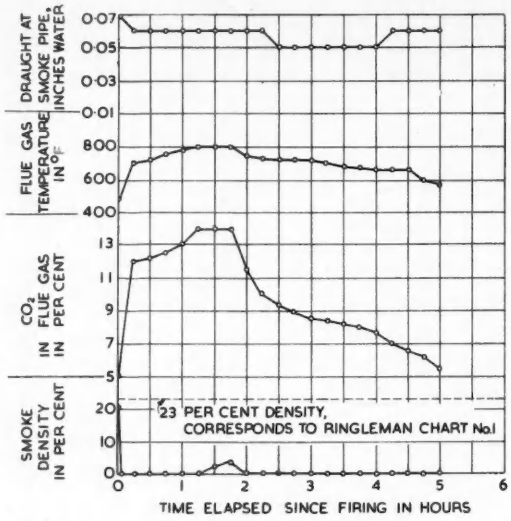
Significant Performance Data from the Special Test.

Performance data recorded during the special test of the second design are shown in graphical form in Fig. 5. The data shown in Fig. 5a were taken while the fuel was being consumed at the maximum burning rate attainable with the amount of draught which was used. The average burning rate during the 5-hr period was approximately 10 lb per hr. The fact that the flue gas temperature did not exceed 800° F indicates that a furnace of this type cannot be overheated if it is installed with a draught regulator which limits the draught to an amount approximating 0·06 in. of water. It may be noted from these data that the proportion of CO_2 in the flue gas reaches a maximum of 14 per cent when the furnace is fully charged and when a maximum burning rate is maintained for more than 1 hr after firing.

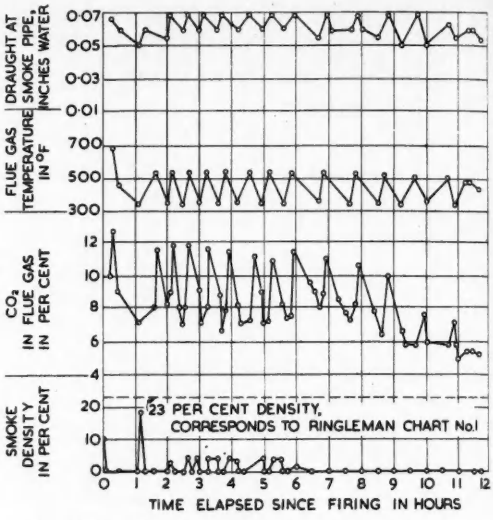
The data shown by the set of graphs appearing in Fig. 5b were taken while the fuel was burned at a moderately high rate approximating 6 lb per hr. During the 12-hr period of this test the dampers were closed when the temperature of the flue gases exceeded 550° F and were opened when this temperature was reduced to 350° F. The graph of the flue gas temperature indicates that the fire responded readily to a change in the position of the dampers at all times throughout the period. The graph showing the percentage of CO_2 in the flue gases indicates that there is considerable variation in this performance item when the position of the dampers is frequently changed. The average percentage of CO_2 for this test period was approximately 9·0 per cent.

Graphs which indicate the results obtained from a 24-hr period in which the fuel was burned at a medium rate approximating 3½ lb per hr are shown in Fig. 5c. During this period an attempt was made to keep the temperature of the flue gas constant at 300° F. During the fore part of the period, when the fire was most responsive, the dampers were closed nearly all the time ; near the end of the period, when the fire was not very responsive, the dampers were open continuously. These data indicate that satisfactory heating performance may be achieved with a hand-fired furnace of this type by giving it attention only once each 24 hr during mild weather and during moderately cold weather. However, the low percentage of CO_2 during the last half of the period indicates that better combustion efficiency would have been achieved if the furnace had been refired after 12 hr of operation.

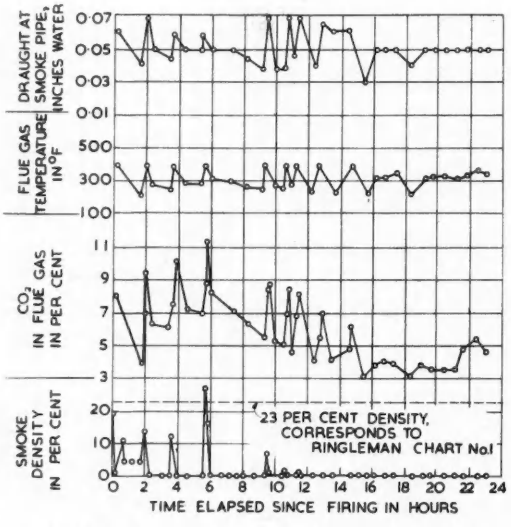
Fig. 5d shows two sets of graphical logs, each covering a 24-hr test in which the fuel was burned at a very low combustion rate except for a brief period after firing the furnace.


DRAUGHT AT SMOKE PIPE, INCHES WATER
FLUE GAS TEMPERATURE IN °F
CO2 IN FLUE GAS IN PER CENT
SMOKE DENSITY IN PER CENT
23 PER CENT DENSITY, CORRESPONDS TO RINGLEMAN CHART No.I
TIME ELAPSED SINCE FIRING IN HOURS

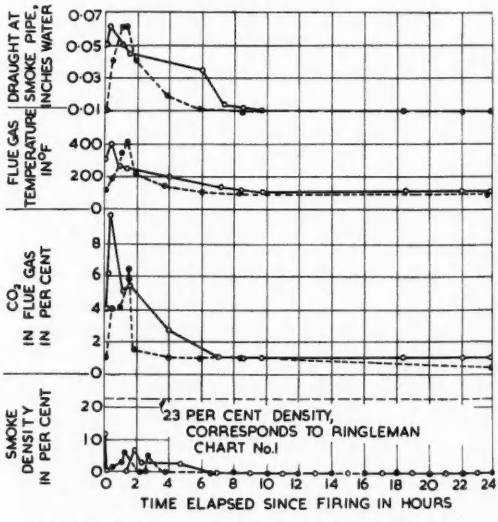
(a)—Maximum burning rate. Dampers open continuously.


DRAUGHT AT SMOKE PIPE, INCHES WATER
FLUE GAS TEMPERATURE IN °F
CO2 IN FLUE GAS IN PER CENT
SMOKE DENSITY IN PER CENT
23 PER CENT DENSITY, CORRESPONDS TO RINGLEMAN CHART No.I
TIME ELAPSED SINCE FIRING IN HOURS

(b)—High burning rate. Flue gas temperature maintained at an average value approximating 450° F.


DRAUGHT AT SMOKE PIPE, INCHES WATER
FLUE GAS TEMPERATURE IN °F
CO2 IN FLUE GAS IN PER CENT
SMOKE DENSITY IN PER CENT
23 PER CENT DENSITY, CORRESPONDS TO RINGLEMAN CHART No.I
TIME ELAPSED SINCE FIRING IN HOURS

(c)—Medium burning rate. Flue gas temperature maintained at an average value approximating 300° F.


DRAUGHT AT SMOKE PIPE, INCHES WATER
FLUE GAS TEMPERATURE IN °F
CO2 IN FLUE GAS IN PER CENT
SMOKE DENSITY IN PER CENT
23 PER CENT DENSITY, CORRESPONDS TO RINGLEMAN CHART No.I
TIME ELAPSED SINCE FIRING IN HOURS

(d)—Low burning rate. Dampers closed throughout the two tests except for a short period at beginning.

Fig. 5. **Graphical logs showing data taken during special test of second design.**

The principal difference between the two test conditions shown by the two sets of graphs was in the temperature of the small bed of coke in the furnace when it was fired. At the time of firing in the cycle represented by the graphs which are shown as solid lines, the small bed of coke was red-hot when the furnace was fired, whereas at the corresponding time in the cycle represented by the broken lines the small bed of coke was almost completely " dead," with only a few glowing coals in the interior of the fuel bed.

In the case of the first-mentioned cycle, the fire responded almost instantly and the flue gas temperature reached a value of 400° F within 15 min after the furnace was fired. In the case of the second cycle, approximately the same volume of coke remained in the fuel bed, but it had cooled to the point where only a small portion was still ignited when the furnace was fired. This condition was due to the fact that the dampers had been continuously closed for a period of 18 hr. It may be noted that the temperature of the flue gases at the time of firing was only 104° F. In the second test the fire responded much more slowly after firing and the dampers remained open for nearly 2 hr before the temperature of the flue gas reached 400° F.

The conditions of operation during the two periods for which data are shown in Fig. 5d were designed to simulate actual service conditions during early fall and

Concluded on page 406

The Influence of the Boiling Characteristics of Petrol on the Liquid Film Deposited on the Walls of the Intake of a Combustion Engine

By Ye. A. Chudakoff. (From *Avtomobilnaya Promyshlennost*, No. 12, December, 1948, pp. 2-4, 9 illustrations.)

Experiments have been carried out in the Special Laboratory of the Russian Ministry of the Automobile and Tractor Industry in connection with the effect of the boiling characteristics of an engine petrol on the proportion of fuel deposited as a liquid film in the engine intake. For this purpose, a manifold design was evolved which is claimed effectively to trap the deposited liquid under a wide range of engine operating conditions.

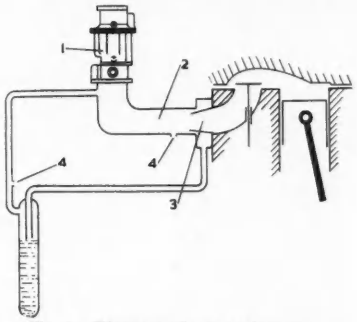


Fig. 1. **Diagram of test equipment.**
1—carburettor, 2—intake pipe, 3—liquid fuel trap, 4—pressure gauge connections.

Fig. 1 gives a diagrammatic view of the set-up used in the investigation. At the flange end of each intake a special liquid fuel trap is inserted, which removes the liquid film before it can reach the intake valve. This trap is reproduced in section in Fig. 2, which is self-explanatory. A pipe conveys the trapped fuel to a collecting cylinder, inside which a vacuum is created through a connection with the intake pipe. The liquid fuel trap is claimed to collect almost all deposited fuel. Three types of petrol were used in the experiments :—(1) "B-70" with a final boiling point of 173° C, (2) a winter motor fuel with a final boiling point of 188° C, and (3) a summer motor fuel, final boiling point 223° C.

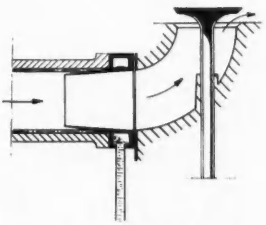


Fig. 2. **Section through liquid fuel trap.**

One series of tests was carried out with the engine idling, cooling water temperature 75° C, crankcase oil temperature 55° C, at speeds ranging between 230 and 700 rpm. Fig. 3 shows that the proportion of fuel deposited on the wall dropped rapidly as the engine speed was increased. It also indicates that the high boiling fractions of the fuel have a considerable influence on the volume of fuel deposited in the intake of the idling engine, even when heated up.

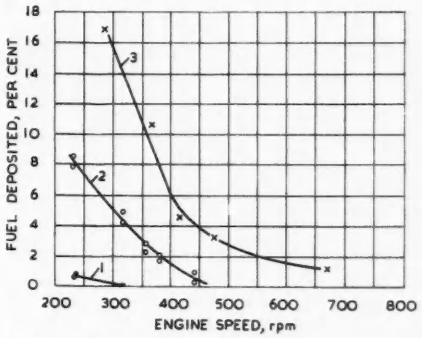


Fig. 3. **Graph showing the fuel deposited as a percentage of the total fuel consumption *vs* engine speed. (Engine idling.)**

Further experiments were made under "starting" conditions, i.e., at an engine speed of 450-500 rpm, with the throttle 10 per cent open, and water and air temperatures of 12 and 18° C respectively. As shown in Fig. 4, the proportion of fuel deposited—varying between 40 and 48 per cent—was greatly increased when compared with the first series of tests, but the difference between the individual types of petrol was reduced. The scatter of individual points was caused by unavoidable variations in temperatures. Again, the higher boiling petrol tended to deposit a greater proportion than the lower boiling fuel.

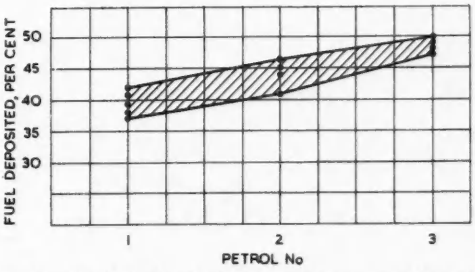


Fig. 4. **Graph showing the fuel deposited as a percentage of the total fuel consumption when starting, for three different types of petrol.**

It is concluded that with the engine idling, even when fully warmed up, the proportion of liquid fuel deposited on the walls of the intake is greatly affected by the heavy fractions boiling above 180° C, so that engine petrol should contain as little as possible of these fractions.

When starting a cold engine, the effect of the heavy fractions on the volume of fuel deposited is comparatively small and it seems to be more influenced by the intermediate fractions. The proportion of deposited fuel is, however, much greater in this case, and to reduce this, preheating of the engine prior to starting is recommended.

In addition to the recommendations outlined above, the developed liquid fuel trap—possibly modified and improved in the light of experience gained on the road—is proposed as a very effective means of eliminating the liquid fuel film and its harmful effects.

DESIGN TRENDS AND T

OF MACHINE TOOLS

BY TIBOR HA[illegible] MECH.

MILLIN
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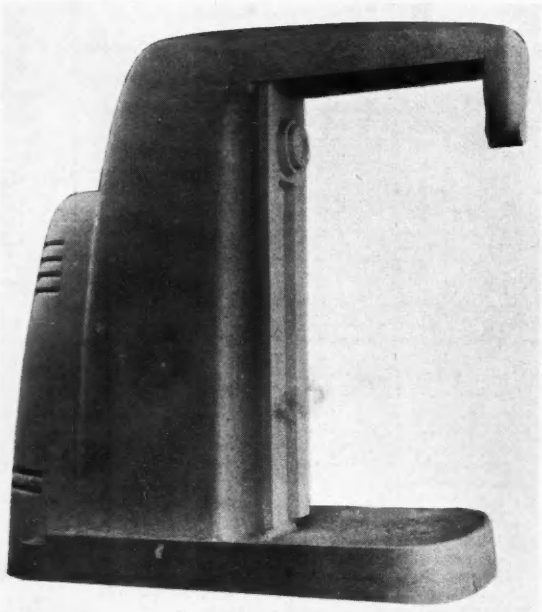
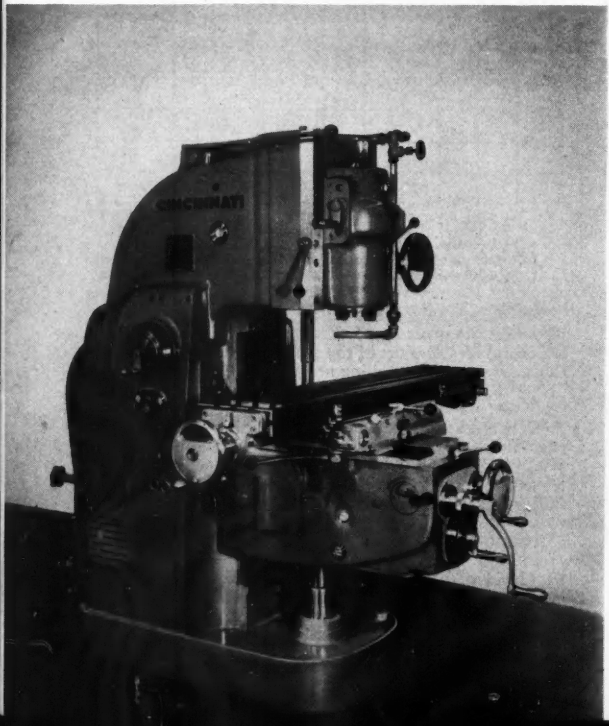


Figs. 53 and 54 (left). **Plaster model of a new horizontal milli[illegible] by Prof. Zdeněk Kovář.** (Side view.)



General

LATHES, which have been discussed in previous issues*, possess the functional feature of a rotating workpiece and a travelling or feeding tool. In other words, turning is a method of removing metal with a non-rotating tool. Milling and grinding processes are characterised by their function of removing metal with a rotating tool, the work travelling or feeding past the cutter or the grinding wheel. Although there is functional similarity between these two machine tools, they differ greatly in construction and appearance, this being due to the fact that the degree of metal removal is different. Furthermore, in the case of grinders, there are fewer operations to allow for.

In the preceding instalments of this series of articles, an attempt has been made to trace national trends in design, but, as could be seen, there are no clearly defined characteristics. Therefore, in the following descriptions and illustrations of machine tools the aim is to seek the contemporary idiom in design as a result of technical progress and following aesthetically satisfying forms.

*See July, August and September issues of THE ENGINEERS' DIGEST.

Fig. 56 (left). **Cincinnati vertical milling machine, No. 2MI.**

E STYLE

OR HA MECH.E., A.F.R.AE.S.

Milling Machines

Apart from special types, milling machines can be conveniently divided into two groups : knee-and-column milling machines and production (bed) type milling machines.

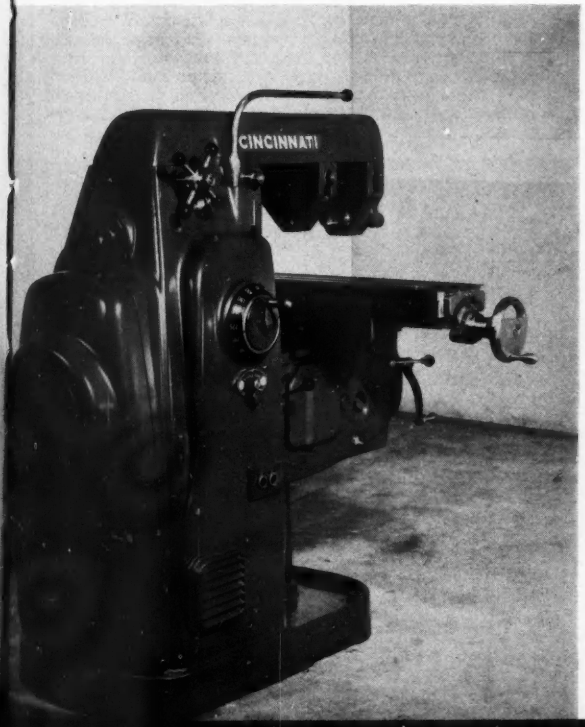
KNEE-AND-COLUMN MILLING MACHINES.

Among milling machines, the knee-and-column type machines represent the general purpose machine tool. They may be subdivided into three groups : horizontal (plain), universal and vertical.

Let us look at the main elements involved in the horizontal milling machine. They are the horizontal spindle, the column, the knee, saddle, table, overarm and the speed and feed change mechanisms. Vertical, transverse and longitudinal movements or positionings of the workpiece are available. Vertical movement is obtained by the mechanism that attaches the knee to the column, transverse movement by moving the saddle in relation to the knee, and longitudinal movement by moving the table relative to the saddle.

The sole difference between horizontal and universal milling machines is the additional fourth movement that allows swivelling of the table in a horizontal plane. The universal milling machine derives its name from this additional movement, and should not be confused with horizontal milling machines convertible by means of swivel attachments to the vertical type, the latter, of course, being characterized by the vertical spindle.

The knee-and-column machines are of great interest to the industrial designer as an example of a machine



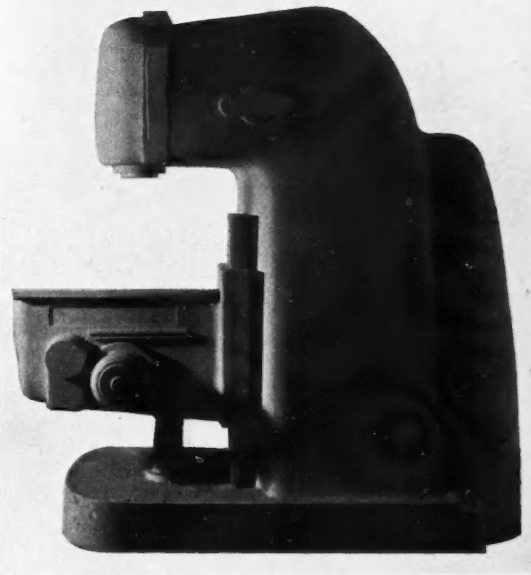


Fig. 55. **Plaster of Paris model of a new vertical miling machine by Prof. Zdeněk Kovář.**

form, various elements of which can be balanced asymmetrically. The harmonious integration of the component forms of the machine to a balanced entity is another most important requirement which, as in any other form, must be achieved in order to be aesthetically satisfying. Functionally, great rigidity is required by the column and overarm, and this is bound to be reflected visually in good design. A plaster model of a horizontal milling machine of Czech design[15] is illustrated without knee and table in Figs. 53 and 54, showing the unity of form generally aimed at in contemporary machine design. The motor and transmission elements are completely enclosed by the column and a detachable housing. The size and distribution of ventilating louvres in this housing have been carefully thought out. Another plaster model, by the same designer, Prof. Zdeněk Kovář, Fig. 55, represents a vertical milling machine with knee, but without table, and is intended to serve here as a further example of good form. In showing these plaster models the reader's attention is drawn to this three-dimensional tool of the industrial designer which he uses in much the same way as the sculptor in arriving at harmonious forms.

In the following illustrations and descriptions of machines actually built, we shall touch upon desirable features that may contribute to the contemporary idiom. In view of space restrictions, technical features are described with reference to one particular make, but it must not be inferred that these features are exclusive to that make. Another reason for adopting this method is the desirability of logical sequence with the minimum of repetition.

The American Cincinnati horizontal miller No. 2MI

Fig. 57 (left). **Rear view of Cincinnati horizontal milling machine, No. 2MI.**

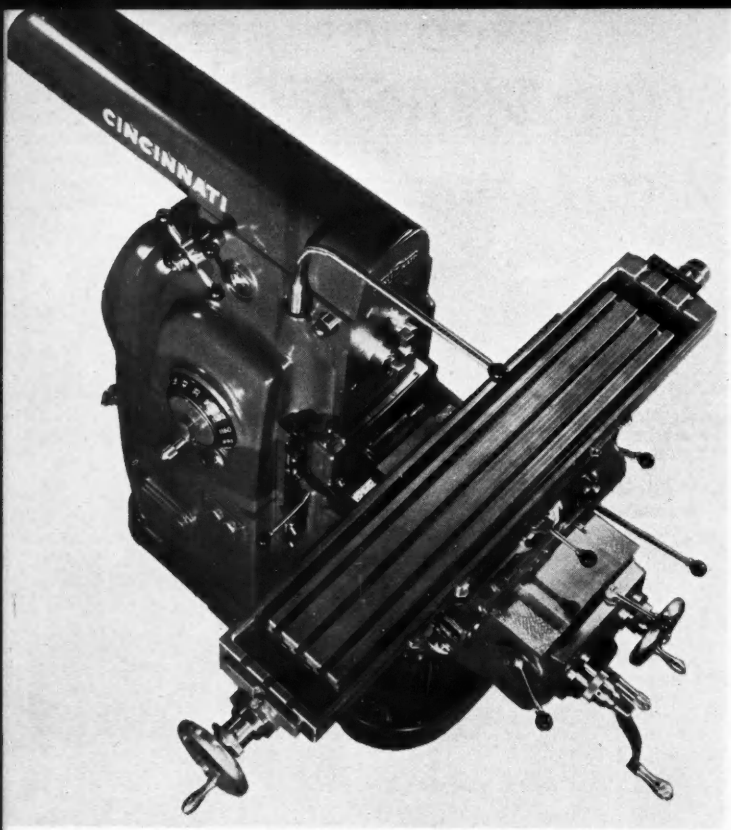


Fig. 58 (left). **Top view of Cincinnati No. 2MI horizontal milling machine. Overarm withdrawn to extreme position.**

Fig. 59 (below). **Cincinnati universal milling machine.**

shown in Figs. 57 and 58 is also built in Britain; of clean lines and excellent shape, this machine is representative of good design that we have come to regard as " modern " in milling machines of the knee-and-column type. Note the sturdy pyramid-shaped column of uniform strength. This construction is visible evidence of a rugged framework, an important requirement for vibrationless milling. The smooth lines of the column and pleasing blend of the units enable easy cleaning. Equally excellent features can be found in the vertical variety of the model shown in Fig. 56.

Another Cincinnati milling machine, illustrated in Fig. 59, shows a workpiece so set-up that the operator has a full rear view of the cutter and the work. He has also complete manual and power rear control. He is seen changing speeds and feeds with *one lever*, which is for hydraulic power. Just above and in front of his left hand are the speed and feed dials, the face disc of which contains a milling speed calculator. Should the job require that he be in front of the machine, he has a clear view of the speed and feed dials from the front operating position. He is not required to walk around to the rear of the machine to change speeds and feeds, as the single lever for speed and feed changes by power is duplicated in front, and thus these changes can be made from either the front or rear operating positions. By replacing the two or three levers used in older machines for manual feed and speed changes by a single lever, damage from sudden engagement of gears is eliminated, as this function is transferred to the machine. Thus, the feed and speed changes by single lever control are performed smoothly and without effort, resulting in a reduction of time and energy and consequent reduction of manufacturing cost. The same considerations apply to hand controls for the adjustment of knee and saddle. In other words, manual controls (see hand cranks facing the onlooker in Fig. 59) are placed at the rear operating position as well as at the front of the machine, and are provided with pull-out type micrometer dials, which have to be pulled, turned to the desired setting, and released. All hand crank levers are automatically

1. Overarm
2. Milling head locking screws
3. Milling head sliding control wheel
4. Micro-reading for transverse motion
5. Automatic feed lever (feed or rapid traverse)
6. Independent feed motor
7. Telescopic coolant return
8. Double action treadle for clutch and brake
9. Column
10. Overarm locking lever
11. Hand-wheel for spindle rotation
12. Three levers giving eight spindle speed ranges
13. Light alloy cover for Vee-belt drive
14. Oil level indicator of the spindle speed gear box
15. Selector giving 5 consecutive speeds in each speed range
16. Spindle drive motor housed inside the column
17. Base forming coolant reservoir

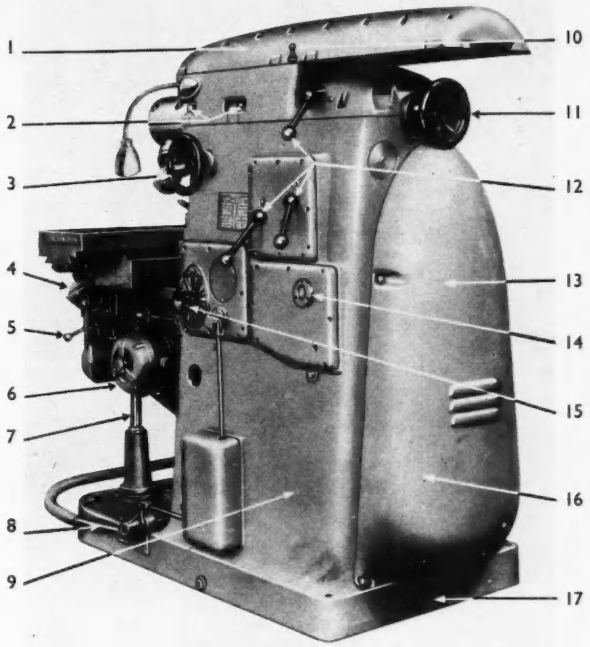
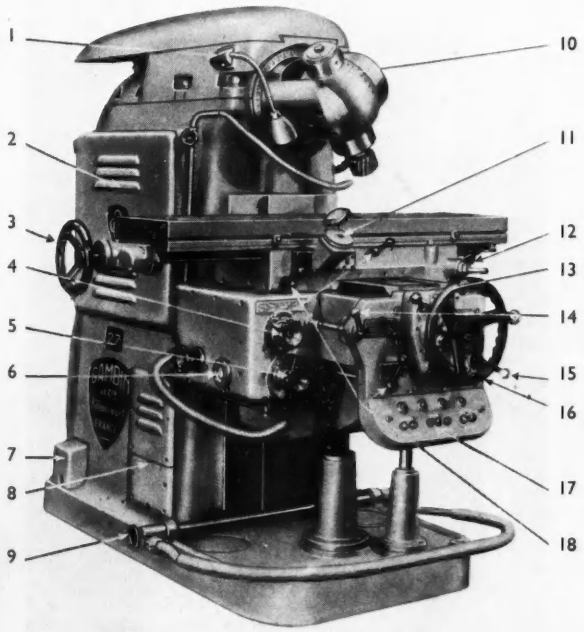


Fig. 60. **Rear view of the Gambin horizontal milling machine with universal head fitted.**

disengaged when the feed or rapid traverse levers are engaged, thus protecting the operator against injury if he forgets to disengage the hand-crank before engaging the feed or rapid traverse.

The French horizontal milling machine Gambin No. 27, a new miller manufactured by C. Gambin & Cie., Billancourt, shown in Figs. 60 and 61, is a well conceived machine of pleasing appearance. It has been



1. Illumination by two lamps switched from the panel in front of the knee
2. Electric control cabinet
3. Longitudinal manual feed control
4. Selector for four consecutive feed ranges
5. Selector for nine consecutive feeds in each feed range
6. Oil level indicator in the feed gear box
7. Fuse box
8. Electric pump cover
9. Coolant level indicator
10. Sliding universal head milling attachment
11. Micro reading for longitudinal traverse motion
12. Manual feed (duplicate control)
13. Reversing lever for all motions
14. Rapid traverse control lever
15. Automatic feed lever (feed or rapid traverse)
16. Unified manual control for all three traverse motions
17. Panel for electric pilot lights and switches
18. Locking levers.

Fig. 61. **Front view of Gambin horizontal milling machine with universal head fitted.**

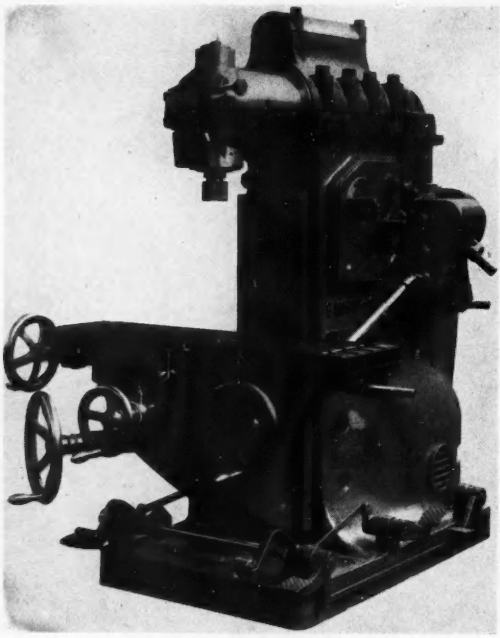


Fig. 62. **Gambin horizontal milling machine No. 21 (older type).**

evolved after investigating the possibilities of complete re-design of the older model, Fig. 62, the only feature of the latter that has been retained in the machine being the sliding universal head milling attachment. It will be noted that, in the older machine, the overarm which was of tubular construction had to be removed when fitting the universal head milling attachment.

In examining the forms of the various members, the present tendency to create harmonious external forms with unbroken surfaces and clean lines has, of course, been followed. It is claimed that the guiding principle was " form follows function."

In the first place, the substantial increase in the power of the machine from 4 to 10 hp and the increase in speed from 710 to 2000 rpm necessitated an investigation as to the best possible balance of masses which were increased owing to the requirement of greater rigidity. The forms of the frame and the knee meet these requirements and result in more massive and better balanced component parts. The new machine provides an interesting comparison with the old type in that it has a box-type ribbed overarm of dovetail construction, leading to a clean and well integrated design. As can be seen from Figs. 60 and 61, the overarm only requires to be retracted when fitting the universal head.

In the second place, the investigation of the new design was directed towards ease of control and operation. The various levers, which stand out well, have been grouped as far as possible in two perpendicular planes. All three motions (knee, saddle, and table) are operated by controls situated at the front of the knee. On the right-hand side of the frame are grouped the speed and feed levers as well as the locking screws and control wheel for the sliding universal head.

Moreover, especially in the case of feed control, the levers have been arranged within easy reach of both the operator's hands, allowing simultaneous operation of two levers when this is required.

The grouping of the controls in the smallest possible number of planes and their rational arrangement in each plane largely contributes to a great general improvement on the older machine from a functional and operational point of view.

Unfortunately, the black-and-white illustrations of the machine do not bring out the value of the use of colour in its functional and aesthetic significance. The present-day recognition and appreciation of the necessity of creating contrasts has led to the following scheme. The whole machine is painted static green. Contrasted with this background, the levers and control wheels are in black and are provided with knobs of different colours according to their functions : control and locking handles in black ; speed and feed change levers in green ; automatic clutching and rapid traverse in red.

The aim towards silence at the high speeds and powers obtained in the new type of machine has led to the widest possible adoption of helical gears. The further objective of obtaining constructional rigidity of the machine in order to prolong its service life has led to the adoption of splined shafts for sliding gears.

Standardisation in design of the different members has been introduced as far as possible. This has made it possible, in particular, to reduce the number of shaft diameters as well as the number of gear modules in the whole of the machine. This standardisation and the need for further economy in production led to the decision to produce only one model in two capacities, using as many identical parts as possible. The initial investigations were directed towards the light-duty type because of the greater space restriction. Thus, a large number of parts developed for the light-duty type could be incorporated in the heavy-duty machine.

Two current Czech universal millers MAS FU1 (Fig. 63) and MAS FU2a (Fig. 64) are illustrated here, as the latter appears to have evolved from the former and approaches the form of the model shown in Fig. 53.

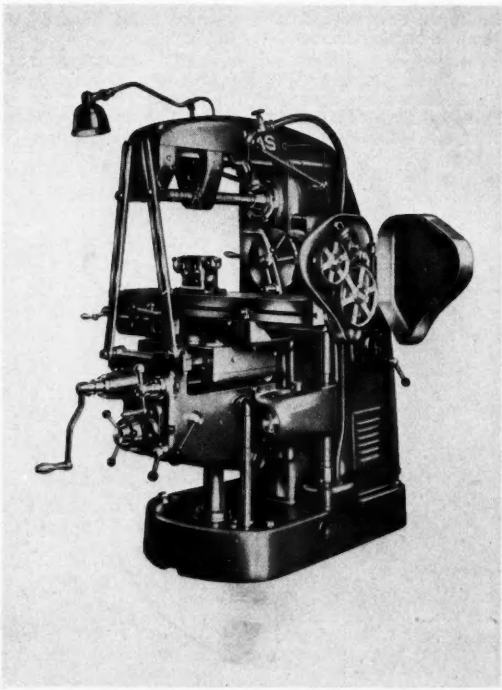


Fig. 63. **Universal milling machine MAS FU1.**

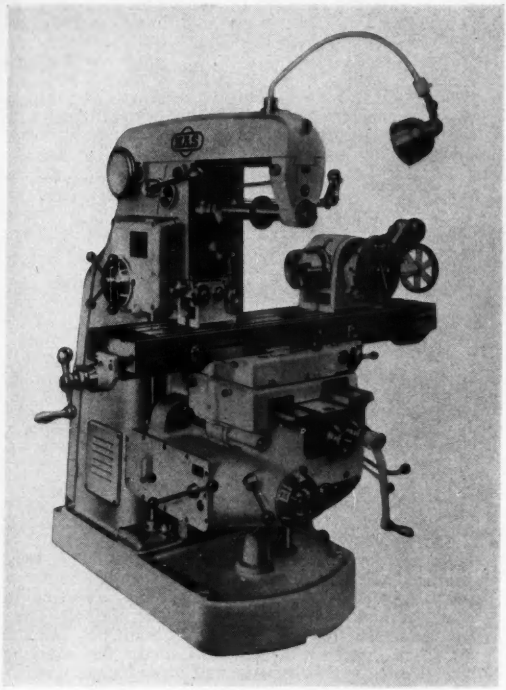


Fig. 64. **Universal milling machine MAS FU2a.**

It may be mentioned in passing that both machines shown are fitted with a dividing head as used for gear milling. In Fig. 63 the open lid shows a conventional lead mechanism for providing the lead to the dividing head. The bracing of the arbor support by two separate braces is an obstruction to the operator and is not only of obsolescent design but lacks aesthetic merit. It requires the adjustment of four locking nuts for any vertical movement of the knee. The single-piece reversible brace with a bridle section at its lower end requires adjustment of two nuts only, and it can be attached left or right to suit the direction of feed or for reasons of accessibility. The power required for the machines described above is not more than about 6 hp. For heavier machines, a still more elegant solution will be described below. Figs. 65, 66 and 67 refer to knee-and-column machines of the Fritz Werner A.G., Berlin, and are characterized by great rigidity, facilitating the use of cemented carbide cutters for heavy cuts, where a 10 hp motor is available. A wide speed range enables large cutters to be used for high-speed milling of light alloys. At the outer end, the knee is supported by a strong brace, which, in the universal type, is connected with the overarm by an upper brace. In this way, a rigid frame is formed (Fig. 67) which need not be opened or adjusted for vertical movement of the knee. This upper brace is made of light alloy; by suitable ribbing, it is made as strong as a cast iron brace, yet it

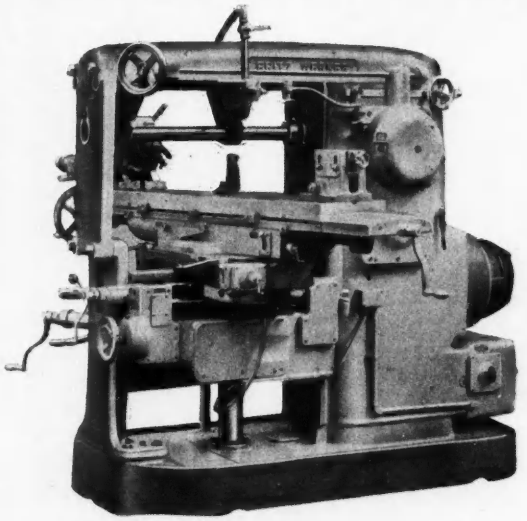


Fig. 65. **Universal milling machine Werner No. 2212.**

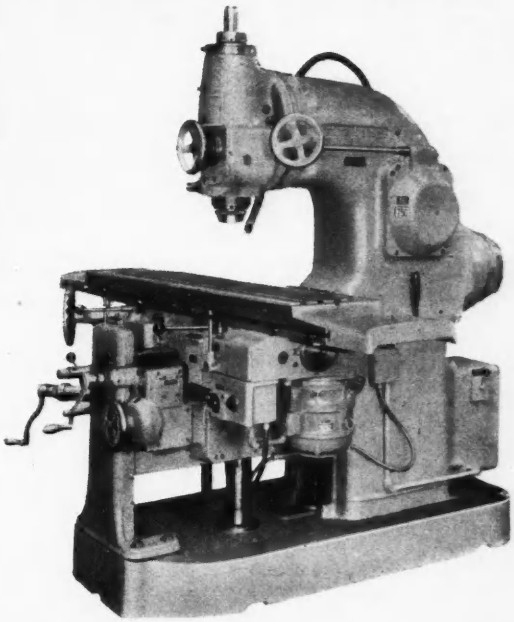


Fig. 66. **Vertical milling machine Werner No. 2232.**

can be easily lifted with one hand. The operating controls of the Werner miller will be described with reference to the vertical type shown in Fig. 66. A horizontal ball-grip lever and a vertical ball-grip lever can be seen at either end of the saddle. These are duplicated controls, the vertical lever being for manual intermittent longitudinal rapid traverse control, while the horizontal lever is a "single-lever" longitudinal power feed control. The function of these two levers will be clear from Fig. 68. There is another ball-grip lever just visible in Fig. 66, which is the control lever for transverse and vertical power feeds, but this is not shown in Fig. 68.

Single-lever Control: When disengaged, the control lever is in the position A (Fig. 68). After the motor has been switched on for the desired direction of rotation, the control lever is turned to the position B, thereby engaging both the spindle and the coolant pump. When the lever is further advanced to C, the automatic feed is

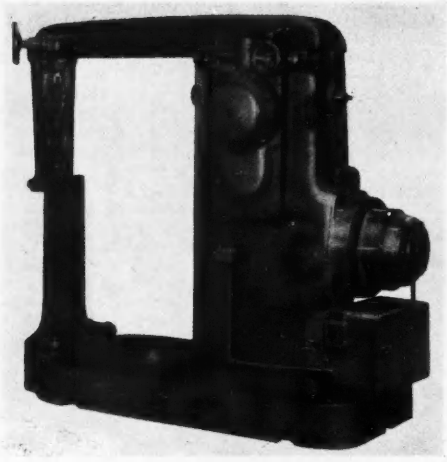


Fig. 67. **Base, column, overarm and brace of milling machine shown in Fig. 65.**

thrown in. Thus, the feed can only be engaged when the spindle is running. When turning the lever back from position C, first the feed is positively cut out (position B) and then the spindle (position A). Moving the lever beyond A to D, the spindle is instantly stopped by a brake. On releasing the lever at D, it returns automatically to the " off " position at A.

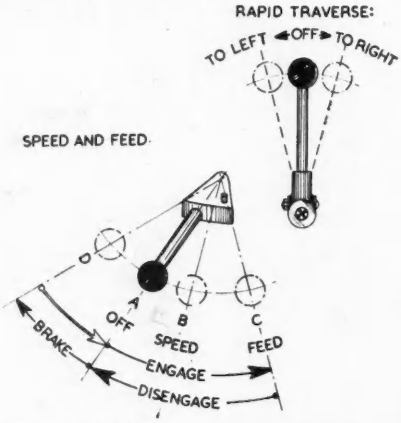


Fig. 68. **Longitudinal power feed and rapid traverse control of milling machine shown in Fig. 66.**

Likewise, the transverse and vertical power feeds controlled by another " single lever " (not shown in Fig. 68) can only be engaged when the spindle has previously been thrown in by the longitudinal power feed " single lever " (position B in Fig. 68).

Manually controlled intermittent rapid traverse : By moving the rapid traverse lever in the direction of the desired movement, the cutting feed driven by the main motor is disengaged and the rapid traverse driven by a motor attached to the saddle is engaged for longitudinal travel. This rapid traverse movement takes place as long as the lever is held fast ; it is interrupted as soon as the lever is released. When the rapid traverse is cut out, the table stops. The feed is now re-engaged by turning the " single lever " for feed to position C (Fig. 68).

As machining times approach optimum values, it is a general tendency in present-day machine tool design to reduce handling and idle machine time to a minimum (see Lathes, Part I, p. 248, July issue of " The Engineers' Digest ") and thus reduce operator fatigue and manufacturing costs. The " single lever " control is one means to this end. We shall revert to this problem when we come to deal with automatic cycle milling with production milling machines, but at this stage a further simplification of the single lever control will be shown, such as is employed on a German Loewe milling machine (Fig. 69).

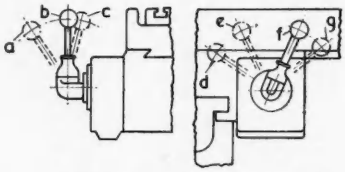


Fig. 69. **Loewe mono-lever control.**
Control lever positions :
(a) rapid approach and feed, (b) table stopped and table braked, (c) momentary stop of table and spindle, (d) rapid traverse to left, (e) feed to left, (f) feed to right, (g) rapid traverse to right.

Another interesting vertical milling machine is the 50-hp driven No. 5CSM model made by Kearney & Trecker, of Milwaukee, Fig. 70. It incorporates a built-in chucking table for simplification of work holding problems.[16] These tables can be used for irregularly shaped workpieces, without resorting to costly special tools and fixtures. An operator's tool tray is cast into the machine table at both ends for hand tools and small set-up accessories. In the chucking table there are five traverse and three longitudinal T-slots ; the longitudinal centre T-slot is standard to accommodate vices, rotary tables, etc. A number of simplified vices are supplied as chucking-table accessories.

In connection with lathes it has been mentioned that design trends have been and are still characterised by changes necessitated by tool developments (Lathes,

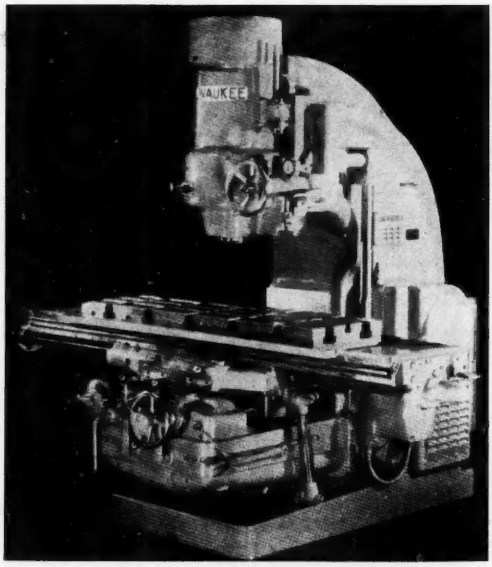


Fig. 70. **Kearney & Trecker vertical milling machine No. 5 CSM.**

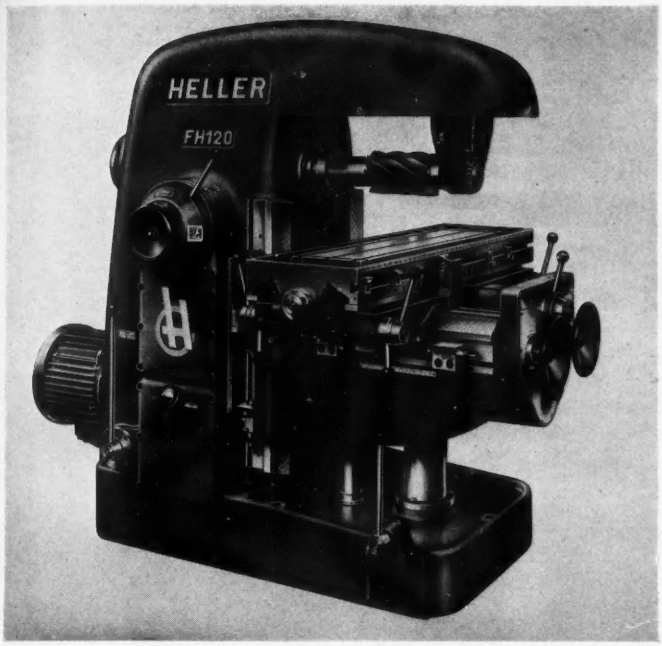


Fig. 71 (above). **Heller horizontal milling machine, No. FH 120.**

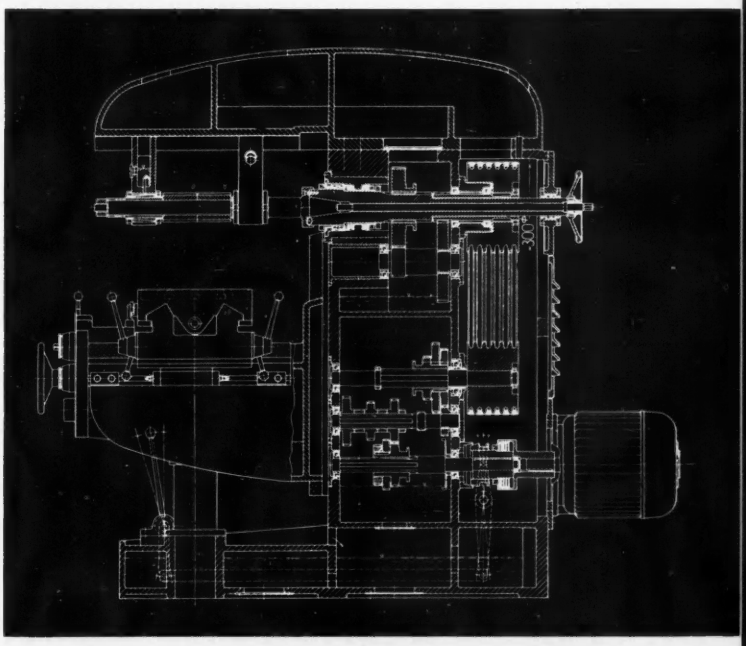


Fig. 72 (right). **Cross-sectional view of the Heller milling machine shown in Fig. 71.**

machine, Figs. 71 and 72, has been built with a view to satisfying the above requirements. All slides are of the prismatic type with maximum spacing, the rigid column being dimensioned to take the heavy cutting loads imposed when removing metal at a high rate. The overarm and arbor supports are of robust construction; the arbors have substantial bearing collars. Bracing can be dispensed with, as the overarm is well ribbed and permanently bolted to the column (Fig. 72). The drive consists of a 30-hp motor which, via a multi-disc clutch; a 9-speed slide gear, and a multi-vee rope transmission, give a direct range to the spindle of 235 to 1500 rpm. Through a reduction gear a further range of 30 to 190 rpm is obtained. Each of the feeds has a separate hydraulic pump for stepless control. Note the speed-selector dial with window, scales for each feed, and dogs for automatic control at the table, Fig. 71, as well as duplicated starting levers, and " single control " levers, lubrication and coolant return, Fig. 72.

A British equivalent machine built for use with tungsten carbide and negative rake cutters is the Adcock & Shipley No. 4AG horizontal milling machine, Fig. 73. When intended for heavy-duty work, the machine

Part I, p. 247). One such development is the increasing use made of negative rake-milling with cemented carbide cutters.[17] Economic employment of this tool requires : (a) high cutting speed ; (b) ample power ; (c) no fluctuation in speed which puts a greater load on the tool ; (d) rigidity of the machine, the tool and the work-holding device. The Heller horizontal milling is driven by a 25-hp motor, but if required for less arduous duty a 10-hp or 15-hp motor is fitted. Twenty-four spindle speeds ranging from 23 to 1260 rpm are available, and the gearing is so arranged that the diameter of the largest size cutter to be used is less than that of the final drive gear wheel. This conception is said to eliminate chatter due to tooth deflection and

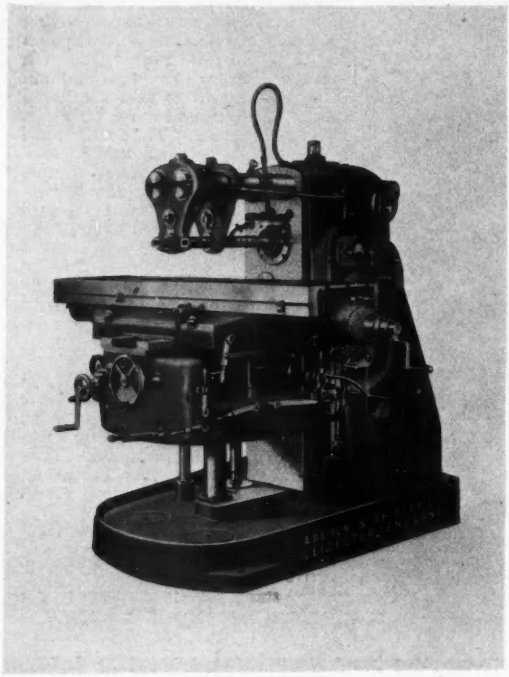


Fig. 73. **Adcock & Shipley horizontal milling machine, No. 4 AG.**

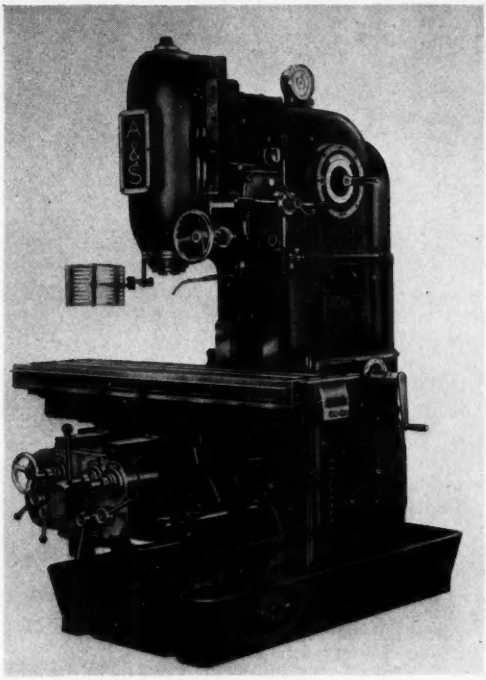


Fig. 74. **Adcock & Shipley vertical milling machine, No. 4 V.**

torsional vibration. A large and heavy final drive wheel behind the spindle nose bearing acts as a flywheel, found to be indispensable when milling with carbide cutters with negative rake. It is worth mentioning that when using the latter tools, the use of a coolant can be dispensed with, as there is no increase in temperature. This is due to increased heat removal with the chips. A vertical milling machine of the same firm, No. 4V, is shown in Fig. 74.

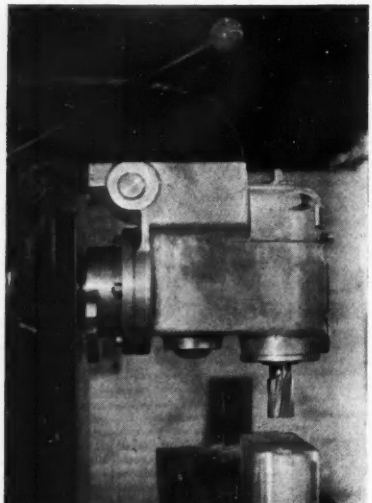


Fig. 75. **Vertical-head milling attachment made of aluminium alloy.** (By courtesy of Aluminium Development Association.)

In the preceding papers of this series the advantages inherent in aluminium alloys as applied to machine tools have been stressed (Lathes, Part I, p. 247). The lathe base shown in Fig. 40 (Lathes, Part III, p. 328) produced as an aluminium alloy casting weighs only 258 lb. With heavy duty machines, and with milling machines requiring rigidity, it may not be possible to use light alloys for machine frames. However, for parts not highly stressed, especially for those requiring repeated removal and re-fitting, a good case can be made out for light alloys. The overarm brace, Fig. 65, and arbor supports on the Cincinnati miller, Fig. 57, are examples of the correct application of light alloys to machine tools. Also belonging to this group are milling attachments, one of which is shown in Fig. 75 fitted to the British Parkson No. 1NA universal milling machine. This vertical head-milling attachment, as originally supplied, weighed 128 lb. Re-designed for casting in aluminium alloy it weighs 46 lb complete with gearing and cutter. Block and tackle which were formerly required for changing the head are now unnecessary, fitting time thus being reduced.

(To be continued).

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WORKSHOP TECHNOLOGY

A New Flame Cutter

By L. G. Buckle.

The writer has been closely associated with the gas cutting industry for almost forty years, both in the U.S.A. and, latterly, in Great Britain.

During this period, tremendous progress has been made in the adaptation of gas to the requirements of the metal industries for the flame cutting of ferrous metals, but little progress has been made towards economy in the use of industrial gases necessary to the process.

As the result of an intensified study of costs involved in this process, a new torch has been developed by the Buckle Flame Cutter Co. Ltd., of Oldfield Lane, Greenford, Middx., England, which is designed to maintain or increase the cutting speed as compared with torches in general use, and at the same time to keep the consumption of fuel gas as low as possible. In particular, it was aimed to produce a torch which is self-balancing under recommended pressures in order to ensure efficiency when in the hands of semi-skilled operators.

Flame cutting is essentially a process of assisting the combustion of ferrous metals by the application of oxygen along a prescribed path. The pre-heating flame is merely a means of liquefying ferrous metals in order to create conditions conducive to the commencement and maintenance of the combustion of these metals. When metal has been prepared to "kindling point" by the application of the pre-heating flame, and an oxygen jet is supplied to the metal, the combustion or oxidation of the metal itself sets up a tremendous source of heat. Theoretically, this source of heat is in itself sufficient to continue the process of cutting along the prescribed path. Under ideal conditions, with a mechanically borne torch, the writer has himself succeeded in cutting clean ¾-inch plate for 29 lineal inches with the pre-heating flame entirely extinguished.

In general practice, however, it is necessary to hold the "kindling point" in advance in order to break up scale or to safeguard against the effects of vibration, particularly in hand operation.

The Buckle flame cutter is designed to take advantage of what may be termed the "secondary source of heat," that is, the heat provided by the metal in combustion and, in effect, to conserve such quantity of the supplied gases as may be conserved without reducing the cutting speed.

No claim is made to the conservation of oxygen through the cutting jet. The combustion of ferrous metals depends on their carbon content and alloy constituents and cannot be enhanced by increasing the pre-heating temperature beyond the combustion limits of the respective metals.

Thus, conservation of oxygen, although it has proved on average to be approximately 13½ per cent overall in actual field practice, may be considered to be due only to the maintenance of balance in the pre-heating flame.

On the basis of 100 cu ft of oxygen used in a given operation, an average of 75 cu ft is necessary for the cutting jet in the standard torch. The consumption of oxygen in the standard torch is, therefore, an average of 25 cu ft for the balancing of the pre-heating flame, whereas, although the Buckle torch equally requires an average of 75 cu ft for the cutting jet, it only uses an average of 11·5 cu ft of oxygen in the pre-heating flame, which is equivalent to a reduction of 54 per cent of oxygen in the pre-heating flame itself.

As it is highly necessary to maintain perfect balance of the neutral flame, it follows that a particular saving in oxygen must balance with a commensurate saving in fuel gas. Thus, an examination of the accompanying table will show an average saving of 55 per cent of fuel gas.

If economy is attempted with a standard torch by valving down the normal supply of heating gas, the starting speed is greatly reduced. In practically all classes of hand cutting, rapid starting is of prime importance, particularly on scaly or rounded surfaces, where the applied heat is largely deflected.

The entire objective of the Buckle principle is to equal or surpass normal starting speed and to maintain only sufficient applied heat to carry on combustion.

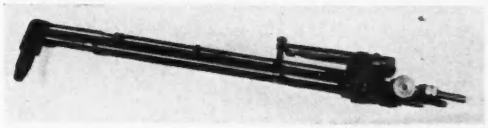

Fig. 1. **The Buckle hand cutter.**

Construction and Operation of the Buckle Flame Cutter.

The general design of the hand cutter is on conventional lines, as shown in Fig. 1; a leverage action, however, is exerted on the main cutting valve towards the head of the torch, as distinct from the action of the "butterfly" valve sometimes employed, which operates crosswise and is considered to have a tendency to deflect the cutter from its correct path. The Buckle cutter is considerably lighter in weight than cutters in general use in Great Britain, but is particularly robust at the head, in view of the regrettable inclination of some operators to use the torch as a hammer.

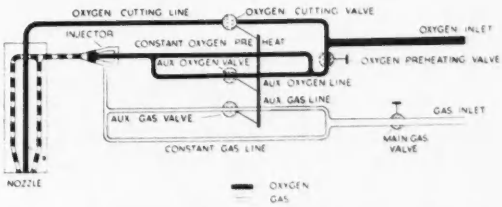

Fig. 2. **Diagrammatic lay-out illustrating the operation of the Buckle flame cutter.**

The patented features are contained within the main body and may perhaps be regarded as constituting two torches in one, as shown diagrammatically in Fig. 2.

When the cutting lever is depressed and the cutting valve is closed, the pre-heating oxygen and the fuel gas are each fed to the nozzle to its full capacity through two separate balanced channels.

When the cutting valve is opened by releasing the lever, one of each of the pre-heating and fuel gas channels is automatically closed and the nozzle is only fed through the other channels, these being ducted to achieve neutral flame balance.

The valves which supply the additional source of heat to facilitate quick starting are directly coupled to the main oxygen cutting valve. Thus, every action of the cutting valve for re-starting creates an immediate change in the volume of the pre-heating flame, increasing or decreasing it according to whether heating or cutting is required.

Perfect neutrality of the flame being maintained, its appearance is not greatly changed. As a matter of fact, the operation of the cutter is more readily perceptible by the ear than the eye. If the cutting orifice of the nozzle be plugged, for instance, by packing it with asbestos string, the sound effect of the changing flame as a result of the change of volume is quite evident. The balancing of both supply channels has been so arranged as to ensure perfect flame balance with both the gas and oxygen valves wide open, and this greatly enhances the performance of semi-skilled operators.

The cutter is designed to combine the most valuable features of the injector and high-pressure principles, the high-pressure torch being designed to achieve balanced mixture through ducts in the head or nozzle, while the injector or low-pressure type is designed to achieve mixture on the injector or Venturi principle. It is considered that a combination of these principles in proper balance is highly desirable. To assure maximum efficiency, cutters can be supplied balanced for gas, such as dissolved acetylene, propane or coal gas, as required. The balancing features, however, are readily interchangeable on the job, should it be necessary to change the gases in use.

Fig. 3. **Cut on 5 in. mild steel with propane, 5/64 in. nozzle, 22 ft per hour.**

This offers great freedom of action for special requirements. For instance, in profiling to finish, a sharp clean top edge is often greatly desirable, and in this connection attention is directed to the 5-in. cut with propane as shown in Fig. 3.

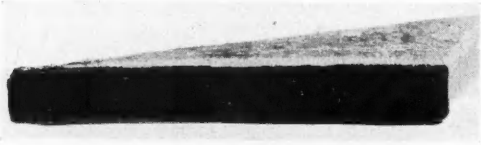

Fig. 4. **Cut on 3/4 in. mild steel with propane, 1/16 in. nozzle, 100 ft per hour.**

In cutting very thin metal, it is essential to avoid excessive pre-heating and consequent melting. The Buckle torch can be supplied to deal with this problem by the introduction of restrictive means for adapting the flame to any given work with the valves fully open.

As the result of an intensive study of nozzle development, the splined two-piece nozzle with copper external is favoured, splining being employed for all types of gases, including acetylene.

The cutter is designed for speedy repair and re-assembly, the cutter being parted and the injector being exposed by loosening two nuts.

Performance.

The test results shown in the accompanying table are a selection from a large number of reports submitted by various official and industrial organisations. It should be clearly pointed out that all these tests have been carried out by operatives in the employ of these organisations, the Buckle Flame Cutter Co. furnishing only the equipment. All tests were made through flowmeters graduated in mm and it will be noted that the economies achieved have surpassed the claims of the manufacturers.

TESTS: 1. 2. 3. Machine Cutting, using D/Acetylene and Oxygen.
TESTS: 4. 5. 6. Machine Cutting, using Pyro Gas and Oxygen.
All trials carried out using 1/16 in. nozzles in both cutters.

TEST 1.

Thickness of plate 1/2 in. — Gas pressure (Buckle 6 psi) (Standard 8 psi)
Cutting speed 70 ft/hr — Oxygen pressure 45 psi

GAS		OXYGEN
Standard Torch	32 mm	63 mm
Buckle Torch	5 mm	39 mm
Saving: 27 mm = 84·3%		24 mm = 38·1%

TEST 2.

Thickness of plate 1 in. — Gas pressure 8 psi
Cutting speed 55 ft/hr — Oxygen pressure 50 psi

GAS		OXYGEN
Standard Torch	31 mm	66 mm
Buckle Torch	10 mm	40 mm
Saving: 21 mm = 67·7%		26 mm = 39·4%

TEST 3.

Thickness of plate 1 1/2 in. — Gas pressure 8 psi
Cutting speed 45 ft/hr — Oxygen pressure 60 psi

GAS		OXYGEN
Standard Torch	25 mm	66 mm
Buckle Torch	9 mm	47 mm
Saving: 16 mm = 64%		19 mm = 28·8%

TEST 4.

Thickness of plate 1/2 in. — Gas pressure 4 psi
Cutting speed 60 ft/hr — Oxygen pressure 45 psi

GAS		OXYGEN
Standard Torch	14 mm	59 mm
Buckle Torch	7 mm	47 mm
Saving: 7 mm = 50%		12 mm = 20·3%

TEST 5.

Thickness of plate 1 in. — Gas pressure 4 psi
Cutting speed 50 ft/hr — Oxygen pressure 50 psi

GAS		OXYGEN
Standard Torch	15 mm	59 mm
Buckle Torch	7 mm	52 mm
Saving: 8 mm = 53·4%		7 mm = 11·85%

TEST 6.

Thickness of plate 1 1/2 in. — Gas pressure 4 psi
Cutting speed 40 ft/hr — Oxygen pressure 60 psi

GAS		OXYGEN
Standard Torch	16 mm	70 mm
Buckle Torch	9 mm	62 mm
Saving: 7 mm = 43·7%		8 mm = 11·43%

The usual test procedure consists in speeding up a mechanically borne cutter of the type generally used by the operator, with a given oxygen pressure, to the highest cutting speed at which the severed part will drop off. Flowmeter readings are carefully checked and re-checked during the operation. Pressures and speeds are then left constant, the only change being the substitution of the Buckle cutter for the cutter of standard design.

The cutting procedure is then repeated and a record is taken of flowmeter readings for comparison purposes.

CLASSIFIED ABSTRACTS

Numerous important abstracts which, for lack of space, cannot be published in our main editorial columns, are regularly included in condensed form in this section. Subscribers may obtain photostat copies of all original articles at cost.

CERAMIC ENGINEERING

High-Strength Ceramics for High-Temperature Use

(From *Technical News Bulletin, National Bureau of Standards, U.S.A.*, Vol. 33, No. 9, September 1949, pp. 103-105, 3 illustrations.)

BECAUSE design engineers projected their plans into regions of temperature and stress far beyond the potentialities of known metallic alloys, a survey of non-metallic compounds, especially the oxides, silicates, carbides, and related combinations peculiar to ceramics became necessary.

When the National Bureau of Standards was requested to obtain engineering data on ceramic bodies in tension at elevated temperatures, it was thought advisable to begin the work on materials that could be produced with available industrial facilities. A comprehensive investigation was begun on the high-temperature strength and creep in pure tension of oxide bodies developed at the National Bureau of Standards.

Maximum observed creep rates, for all of the bodies tested, may be summarized as ranging from about 0·0001 to 0·0002 per cent per hour at 1,700° F for the range of stresses used; from 0·0002 to 0·0008 per cent per hour at 1,800° F and a stress of 16,000 psi; and, from 0·0030 to 0·0040 per cent per hour at 1,900° F and 10,000 psi stress. The maximum stress at rupture for four NBS ceramic bodies at various temperatures is given in the accompanying table.

STRESS-TEMPERATURE DATA ON FOUR HIGH-STRENGTH CERAMIC BODIES.

Temperature	Maximum stress			
	NBS ceramic bodies			
	No. 358	No. 353	No. 151	No. 4811C
°F	psi	psi	psi	psi
1,500	13,000	13,000	12,000	14,000
1,700	14,000	13,000	13,000	14,000
1,800	17,000	18,000	18,000	18,000
1,900	8,000	4,000	15,000	16,000
2,100	—	—	—	6,000

Data obtained from the Bureau's tests have revealed that some of the NBS oxide bodies are capable of effectively withstanding high-temperature conditions far better than any other material now in use. In fact, an experimental gas turbine, using blades fabricated from the oxide body of the most promising strength and creep characteristics, has been operated successfully in the Cleveland Laboratory of the NACA.

GAS TURBINES

Application of Gas Turbines to Mobile Power Stations, and Rail and Ship Propulsion

By A. A. KANAEV. (From *Kotloturbostroyenie, Russia*, No. 5, 1948, pp. 8-12, 10 illustrations.)

WITH present-day knowledge, it is possible to build open-cycle gas turbines up to a rating of 25 MW, and closed-cycle turbines up to 50 to 100 MW. Turbines operating on the closed-cycle principle may, therefore, be more suitable for installation in large ocean-going vessels. As is well-known, a large variety of different arrangements is possible, either with the closed or open cycles, ranging from the simplest scheme, embodying only a compressor, turbine and combustion chamber, to elaborate installations with several combustion chambers, compressors and turbines, and including intercoolers and heat exchangers. The efficiency of the more complicated scheme is considerably higher, but the dimensions of the plant are increased to an extent which renders its use for railway propulsion impracticable. A further disadvantage arises in the need for auxiliaries and cooling water requirements for the intercoolers. For rail propulsion, it is advisable, therefore, to sacrifice some efficiency to achieve simplicity and reliability.

While at present gas turbines can only be run on liquid or gaseous fuels, the Polsunov Institute for Boiler and Turbine Research has carried out some very promising investigations into the use of solid fuels, both in a pulverized and natural state.

For small installations of less than 100 kW, when axial compressors cannot be used, diesel compressors working as gas generators are very suitable. An efficiency of 40 per cent for such an arrangement can normally be obtained with temperatures as low as 450 to 500° C. The disadvantages of the scheme are the inherent shortcomings of the reciprocal diesel engines.

One of the difficulties in the production of gas turbines is the manufacture of compressor blades. They require special machinery and consume a large number of man-hours; this difficulty has now been overcome by a new production method by which the blades can be machined on a standard lathe.

The problem of solid fuels for gas turbine installations is receiving constant attention. The main difficulty is presented by the abrasive action of the ash particles. A process of obtaining extremely fine pulverization of coal to overcome this is mentioned.

Characteristic data for gas turbine installations are given. For land installations, the space requirements are 0·6 to 0·8 m^3/kW and more, while for locomotives and ships the corresponding figure can be one tenth of this value. The weight per kW varies from 80-100 kg and 30 per cent efficiency for land installations, to 12-16 kg and 20 per cent efficiency for locomotives and ships, and 0·2-0·5 kg for aeroplanes.

Comparisons are presented for locomotives with different power sources, a graphic illustration of comparative sizes of mobile power stations being included together with a similar illustration of sizes for ships.

NON-FERROUS METALS

Melting and Casting Zirconium Metal

By W. J. KROLL and H. L. GILBERT. (From *Journal of the Electrochemical Society, U.S.A.*, Vol. 96, No. 3, September, 1949, pp. 158-169, 5 illustrations.)

THIS report deals with the methods for melting and casting zirconium. It has been shown that owing to the high melting point and chemical reactivity of zirconium and titanium, only graphite can be used as crucible material for producing large, commercial ingots. All refractory oxides either react or cannot be used commercially as crucible material.

Arc furnaces may be employed in vacuum or with inert atmosphere to build up ingots in a water-cooled copper mould or in graphite sleeves with varying amounts of contamination depending on electrode and crucible material.

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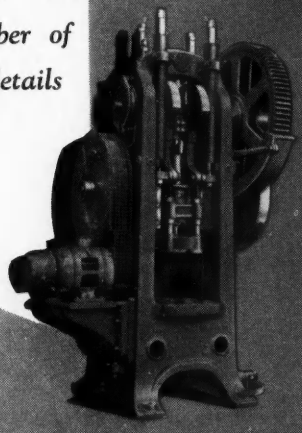

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High-frequency furnaces can produce large castings rather easily when inert atmospheres are employed. With certain restrictions, the same work may be done in vacuum. Use of graphite crucibles gives some contamination with carbon.

Split-tube, graphite-resistor furnaces are particularly suited to casting by the bottom-plug method to give uniform castings only slightly contaminated with carbon. The three-phase furnace shows stirring action of the bath. Castings with 0·07-0·11 per cent carbon are regularly obtained.

Experiments indicate that all three types of furnaces have distinct advantages and disadvantages. The choice as to which one is best depends partially upon the volume of gas to be tolerated in the ingot.

If fully degassed metal is desired, melting in the graphite-resistor vacuum furnace and casting give full satisfaction, especially with regard to low carbon content and freedom from residual hydrogen. High-frequency and arc vacuum furnaces for the production of castings are much more difficult to build and to operate.

Melting under a noble gas does not remove all the hydrogen contained in the metal, but may be entirely suitable for the production of zirconium that will not be used in electronics. The graphite-resistor, high frequency, and arc furnaces are well adapted for this operation.

PLASTICS AND PLASTIC PRODUCTS

Plastics and their Application in the Electrical Industry

By J. C. DERSKEN and M. STEL. (From *Philips Technical Review, Holland*, Vol. 11, No. 2, August, 1949, pp. 33-41, 12 illustrations.)

JUST as in many other fields, plastics are extensively applied in the electrical industry as constructional materials for all kinds of apparatus. Often they are used for these purposes on account of their good electrical properties, whilst in other cases it is their easy mouldability and the good finish that can be given to the products which count most. It is very often possible to synthesize these materials with the properties required for a particular purpose. Of the methods employed in the formation of the macro-molecules characterizing all plastics, the condensation and polymerization methods are discussed. Use is made not only of thermo-setting moulding materials but also, and to an increasing extent, of thermoplastic materials. The most important materials and their specific properties are dealt with briefly. A table gives an idea of the great diversity of these properties. In the moulding of articles from thermoplastic material, four methods are employed: injection, extrusion, pressing and blowing. Finally, a number of applications of plastics in the electrotechnical field is discussed.

Smokeless Coal Heaters

Concluded from page 392

again in late spring. At those times during each year the heating plant is called upon to deliver heat for a few hours in the morning, but more than a very small heat output at any other time causes serious discomfort from overheating. These are the conditions under which it is most difficult to achieve satisfactory results from a furnace burning solid fuel. If the combustion rate is too low during a long period of hold-fire, ignition is lost in all parts of the fuel bed, and the fire must be rekindled. If the combustion rate during hold-fire operation is too high, overheating will occur in the spaces served by the plant. The data shown in graphical form by the solid lines indicate that a hand-fired furnace of the type tested will respond quickly after firing even when only a small amount of coke remains from the previous charge, providing that the dampers have been open for an hour or more prior to firing so that the coke is well ignited. In actual service under thermostatic control, there is usually some demand for heat a few hours before the hour at which the average householder would find it convenient to fire the furnace. Consequently, the coke from the previous charge would usually be well ignited when the furnace is fired, even in early fall or late spring when the weather is so mild that heat loss from the house is negligible or indeed negative throughout the greater portion of the day. In the unusual event that there had been no demand for heat prior to the time of firing, the condition of the fuel bed and the results obtained would approximate those shown by the graphs drawn in broken lines. However, the slow response of the fire would not result in discomfort in the house because the fact that the thermostat had not demanded heat indicates that the house temperature did not decrease below the comfort range during the night.

A study of the data shown in Fig. 5d reveals the fact that the draught and per cent CO_2 stabilised at 0·01 in. of water and 1·0 per cent respectively, approximately 6 hr after the dampers were closed, under the conditions of operation that were used in these two tests. Assuming that all the air entering the furnace passes through the 1-in. dia bleed hole in the secondary and undergrate air damper, the rate at which fuel is burned during this condition of operation may be calculated, inasmuch as the weight of air entering the furnace is determined by the draught measured in the air tube and the weight of air passing through the furnace per pound of fuel burned may be computed from an analysis of the flue gases. A computation of the combustion rate during the condition of operation which prevailed during the latter part of the long hold-fire periods indicates that ignition can be maintained for several hours in the interior of the fuel bed while the fuel is being consumed at a rate which is less than 0·1 lb per hr. Extremely low combustion efficiency is not a disadvantage during a long hold-fire period at a time when there is no heat loss from the spaces served by the heating plant. The only significant performance item is the weight of fuel which must be burned in order to maintain ignition in the fuel bed.

Effective Thermostatic Control of the Smokeless Furnace.

A week-long temperature record was taken at the writer's home and from this record it was seen that the temperature was well maintained at 74° F with only short-time deviations of ±2° F, although the outdoor temperature varied between a high reading of +40° F and a low reading of —3° F. During the week for which the record was made the furnace was fired each morning and again each evening. At each firing the grates were shaken, the fuel bed was levelled, and the coking chamber was filled with fresh fuel, no attention whatsoever being given to the furnace between firings. Immediately before each firing the thermostat setting was advanced several degrees to cause the control system to open the dampers and hold them open during the few minutes that were required to service the furnace. Immediately after the completion of the firing procedure, the thermostat setting was on every occasion returned to 74° F, where it remained at all other times.

From the temperature record shown and the frequency of firing that was employed, it is clearly evident that the second design of the Illinois Smokeless Furnace is very well adapted to thermostatic control and that excellent results can be achieved during cold weather by properly attending the furnace in the morning and again in the evening. Similar results in milder weather can be achieved by one firing every 24 hr.

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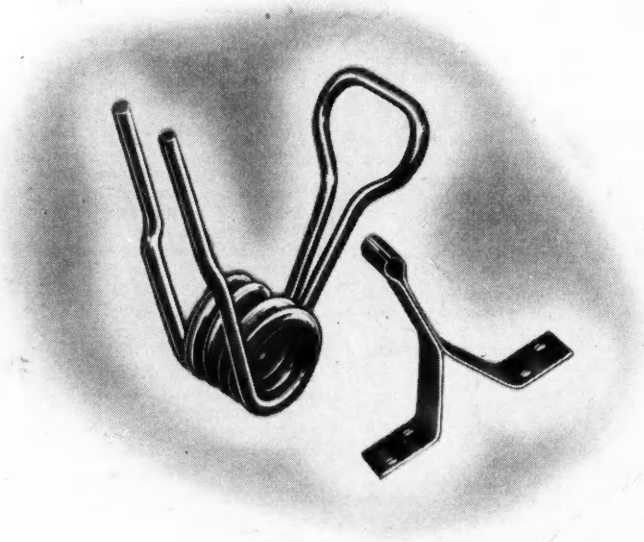

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NEWS OF THE MONTH

PERSONAL

Mr. E. Bruce Ball has been re-elected Chairman and **Mr. J. M. Storey**, vice-chairman of the British Valve Manufacturers' Association.

Mr. A. M. Bryan, J.P., B.Sc., F.R.S.E., H.M. Chief Inspector of Mines, has been elected President of the Institution of Mining Engineers, Salisbury House, Finsbury Circus, London, E.C.2.

Dr. C. H. Desch, F.R.S. has been installed as President of the Newcomen Society.

Mr. G. H. Fletcher, M.I.E.E., has been appointed general manager of the Metropolitan-Vickers Electrical Co. Ltd., Attercliffe Common Works, Sheffield. **Mr. H. Newsam, B.Sc. (Eng.), A.M.I.E.E.,** has been appointed chief engineer, traction-motor department, **Mr. R. P. Knight, A.M.I.E.E.,** assistant manager, and **Mr. H. Taylor,** superintendent of the Sheffield works.

Mr. Gavin Hamilton, F.R.I.C., A.R.T.C., has relinquished his executive duties as general manager of the BTH Lamp & Glass Works, but will continue to be available for consultation. **Mr. T. J. Dagley** has been appointed general manager of the glass factories and also of glass and lamp-component sales; **Mr. S. R. Eade, M.I.E.E.** has been appointed manager of the BTH lamp factories.

Mr. C. H. Hill, M.I.Mech.E., formerly chief mechanical engineer of the Sudan Railways, has been appointed consultant and director of Dolphin Industrial Developments Ltd., Twyford Manor, Buckingham.

Dr. F. C. Johansen, M.I.Mech.E., F.R.Ae.S., has been appointed director of research of the W. and T. Avery Ltd. group of companies. He has also been elected a member of the board of Avery Research Administration Ltd., Soho Foundry, Smethwick, Birmingham.

Sir Philip Johnson has been elected Chairman and **Mr. T. A. Crowe,** vice-chairman of the National Association of Marine Engine builders.

Mr. E. J. Mathieson, M.I.E.E. of Chasetown, near Walsall, Staffordshire, has been appointed electrical engineer of the Government Electricity Undertakings in Nigeria, West Africa.

Mr. R. T. Outen has been appointed deputy chairman and **Mr. Geoffrey W. Hall** has been elected a director in charge of the research and armament development division of the Fairey Aviation Co. Ltd. **Sir Richard Fairey** continues as chairman and managing director of the Company.

Dr. I. G. Slater, formerly director of operational research at the Admiralty, has been appointed director of research and development of the Aluminium division of Tube Investments Ltd.

Mr. David Walker, M.I.E.E., joint managing director of Evershed and Vignoles Ltd., has been elected vice-president of the British Engineers' Association.

Mr. S. E. Walmsley, M.I.Mech.E., has joined the firm of Hitchins, Jervis and Partners, chartered consulting engineers, of 40 Broadway, London, S.W.1., as a partner.

BUSINESS NOTES

Hordern, Mason & Edwards Ltd., of Pype Hayes, Birmingham 24, are opening this month a London Office at 4 Vernon Place, Southampton Row, W.C.1. Tel. HOLborn 1324. Mr. A. Powell-Tuck who has been London Representative of the company will be in charge of the London Office; he will be assisted by Mr. B. H. Chase from the firm's Head Office.

The British Thomson-Houston Co. Ltd. Birmingham District Office has moved into more commodious premises. The new address is Geoffrey Buildings, John Bright Street, Birmingham 1. Tel. Midland 6335.

F. J. Edwards Ltd., 359-361 Euston Road, London, N.W.1., have appointed the Rockley Machinery Co., 28 Market Street, Sydney, as their representatives in Australia for sheet metal working machinery, presses and tin box making machines.

H. W. Kearns & Co. Ltd. have appointed Mr. Gunnar Bonthnon, of Maskinfirma Sigurd Ericsson, Regeringsgatan 74, Stockholm, their sole representative for Sweden.

A. C. Wickman Ltd., Tile Hill, Coventry, will act as sole selling agents in Gt. Britain and some foreign markets for the sale of "Fastraverse" presses, injection moulding machines and die casting machines of the Hydraulic Press Manufacturing Co., Mount Gilead, Ohio, to be manufactured in England by John Shaw & Sons (Salford) Ltd.

Manufacturers', Bankers' and Exporters' Manual. Publishers: Littlebury & Co. Ltd., The Worcester Press, Worcester. 600 pp.

The 1949 edition of this book contains an alphabetical list of manufacturers and exporters of British goods. 2,300 manufacturers and 1200 exporters are listed with useful data on the types of products they export. A list of British Advertising Agents and information on Shipping and Air Travel has been added to this latest edition of the book to which the President of the Board of Trade has written the Foreword.

Industrial Australia. Publishers: The Union Bank of Australia Ltd., 71 Cornhill, London, E.C.3. 78 pp. with three maps.

TECHNICAL CORRESPONDENTS' TOUR OF INDUSTRIES IN THE SOUTHERN REGION 31st OCTOBER—2nd NOVEMBER, 1949.

The Ministry of Supply arranged this tour to give technical correspondents an opportunity to see for themselves the progress that has been made by industry in recent years. It was also intended to provide them with information regarding the efforts made to increase production and step up our sales in dollar-earning markets.

The tour started with a visit to Airspeed Ltd. in Portsmouth, who are mainly engaged in the development of the Ambassador twin-engined airliner. This has been designed expressly for economical and efficient operation on the medium-stage airlines of the world. While the Portsmouth factory is a fabrication centre where much of the detail work is done, fuselage and final assembly, power plant and general development, and finishing work are carried out at the Christchurch factory. Correspondents also had an opportunity to see the well-known Mosquito aircraft under construction.

The next firm on the itinerary was J. Evans and Sons (Portsmouth) Ltd., who are engaged in the manufacture of high-precision machine tools, although their main work is the construction of brushmaking machinery. This development has only been in operation since the War, their first machine being based on German designs. Not satisfied, however, with merely copying existing designs, they have since made considerable improvements and are now engaged in the development of new machines which should further improve output and efficiency. They are striving hard to find an opening in the American market and the management of the factory is to be congratulated on its enterprise and drive.

A visit to Pirelli General Cable Works, in Eastleigh, afforded an opportunity of following the manufacture of cables from the copper mill to the finished product. Correspondents were particularly interested to see the Pirelli continuous lead extrusion machine, which is claimed to be far superior to stroke-type presses. Orders for this machine have been received from all over the world.

The firm of Wellworthy Piston Rings Ltd. started in a very small way by making shells during the first World War, their tools and machinery being used later in the production of piston rings. Since then, the business has grown to such an extent that several factories are now producing 250,000 piston rings per week for aircraft, commercial vehicles, motors, etc., as well as pistons, valve seats, and liners; they also make their own castings. They are exclusive licensees in the United Kingdom for the "Al-Fin" process, which is used for the chemical bonding of aluminium to steel and cast iron—

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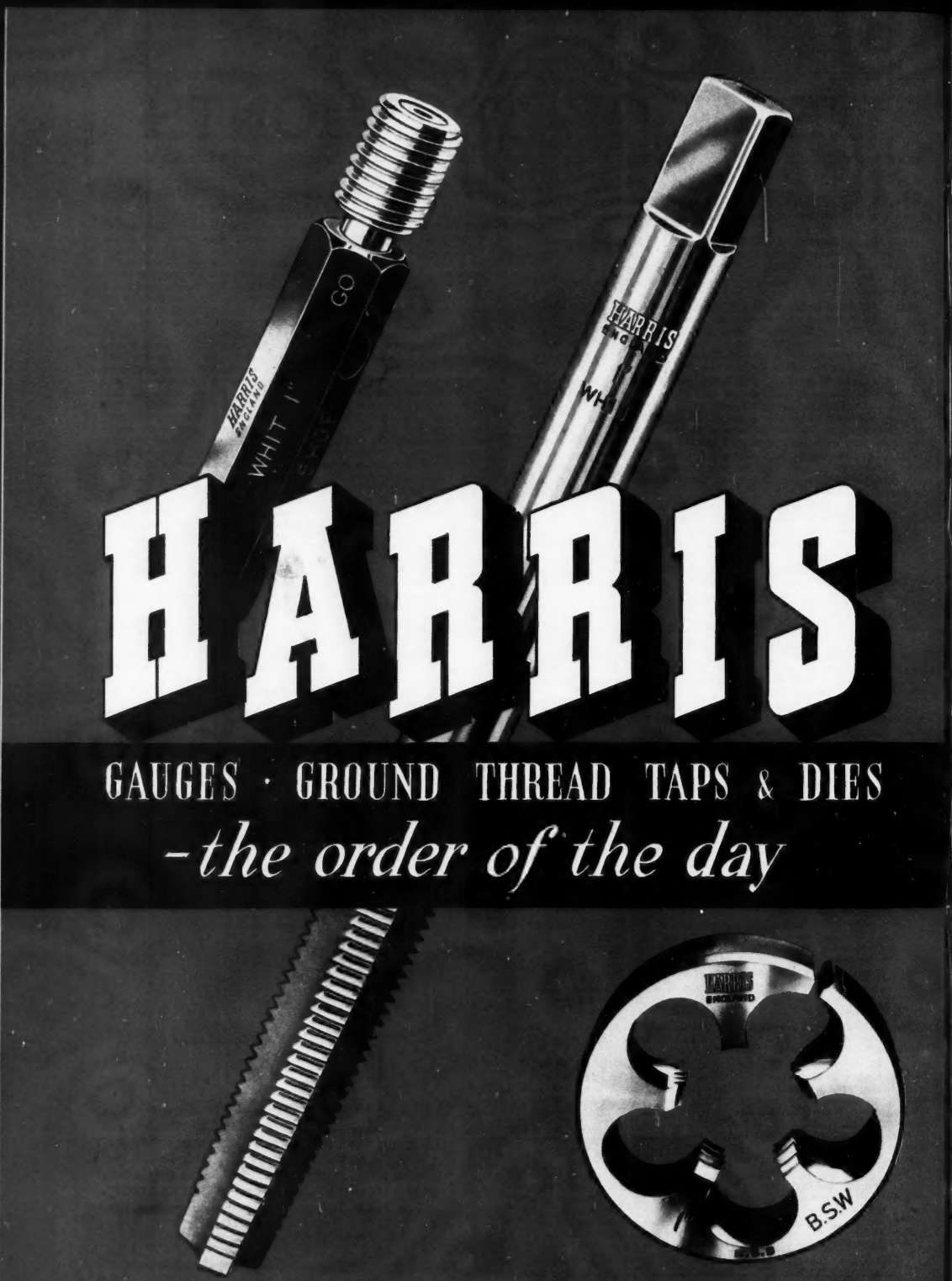
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applied to cylinder barrels, pistons, brake-drums, etc.—allowing a saving in weight whilst increasing thermal conductivity.

Thornycroft, of Basingstoke, the well-known makers of transport equipment, was the next firm to be visited. The Basingstoke factory is solely concerned with the manufacture of heavy motor vehicles, a large proportion of its output being for export, mainly to the Commonwealth countries. It is greatly to be regretted that time did not allow of making a fuller inspection of the many interesting features of this factory.

Finally, the works of Coopers Mechanical Joints Ltd. were inspected. They produce all types of gaskets, the machinery employed being of modern design. An impression of great efficiency was obtained. An interesting feature is that the management has instituted a " Tidiness Campaign " for both factory and executive offices and claims that efficiency and production have increased as a result. Tidiness and the adoption of a colour scheme have done much to reduce careless work and accidents.

After the tour, correspondents were invited to a cocktail party attended by the Minister of Supply, the Rt. Hon. G. R. Strauss, P.C., M.P., which afforded an opportunity for discussion and questions.

It is difficult to form an exact opinion from the technical viewpoint after seeing so many works in such a limited time, but one outstanding feature which should be very encouraging, was that, with very few exceptions, all employees were hard at work, and the impression was gained of a real effort being made to step-up production. If the firms visited can be regarded as a true cross-section of industry in the Southern Region, then productivity is about to rise. As regards equipment, however, much remains to be done, as the average age of machine tools is still far too high, and in many cases it is only due to the skill of the workmen that good products can be produced with the inadequate mechanical means at their disposal. Whilst it is realised that World War II is largely to blame for obsolescence in workshops, we cannot but feel that the effort to re-equip industry with machine tools has not been adequate, especially since this country is now obliged to compete with American methods of production.

The Ministry of Supply is to be congratulated on this excellently organised tour and it is hoped that further tours will be arranged in other areas.

GAS TURBINES for POWER GENERATION in WARSHIPS

The advent of the gas-turbine as a practical prime-mover, with its potential advantages of low maintenance, compactness and light weight, in addition to those of self-contained operation and quick starting already associated with diesel-driven generators, has led the Admiralty to consider the possibility of developing a gas-turbo-generator suitable for H.M. Ships.

The fuel consumption of gas-turbines in their present stage of development, especially when designed for long operating life, is high compared with the diesel although comparable with ship's steam turbo generators, and practical experience is necessary to determine the extent to which high fuel consumption is outweighed by the advantage mentioned above.

The Admiralty have, therefore, placed a contract with W. H. Allen, Sons & Co. Ltd., of Bedford for a 1,000 kW Gas Turbine and Generator for base-load operation. The set is being designed in collaboration with the Bristol Aeroplane Company.

This set consists of an axial compressor of 4/1 pressure ratio, delivering to an annular type heat exchanger, a compressor-turbine and a free power turbine. The free power turbine, while it complicates the governing problem, gives a necessary improvement in part-load performance. The generator is driven through an epicyclic reduction gear.

The following performance details are available :

Maximum continuous rating	1,000 kW.
10 minute rating	1,200 kW.
Fuel	Diesel oil
Estimated fuel consumption at full load	1·07 lb/kW/hr.
Maximum Gas Temperature	720° C (tropical conditions)
Operating life	50,000 hours
Overhaul periods	5,000 hrs. (Major) 1,000 hrs. (Minor).

The set has been designed for operation in both temperate and tropical conditions. Allowance has been made for very high inlet and exhaust losses associated with long trunking in shipboard operation.

The design and construction of this Allen Gas Turbine-driven generator is well advanced and it is expected that development running of the prototype engine will begin early in 1951 on completion of preliminary tests during the autumn of 1950.

" DESIGNING MACHINERY FOR ARC WELDING."

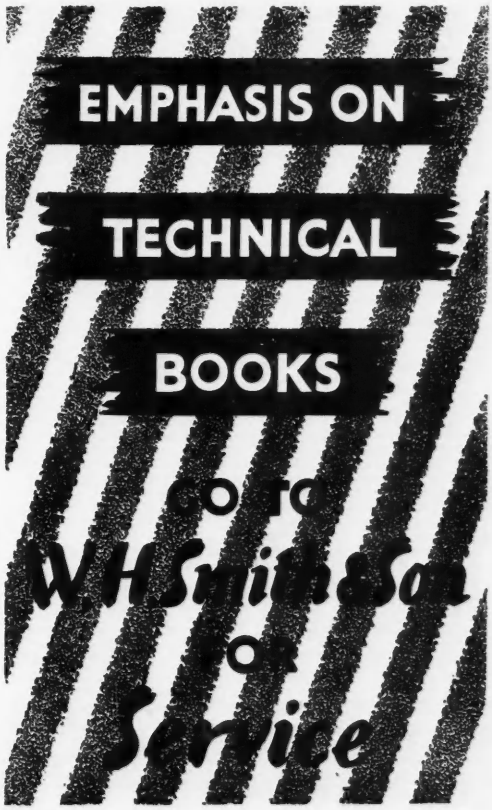
Lincoln Electric Co. Ltd., Welwyn Garden City, have now released the new colour film " Designing Machinery for Arc Welding." The film runs for 15 minutes and is supplied on 16 mm sound-colour prints.

This film shows, with the help of colour animation, how to use the right amount of the right material in the right place ; how cast iron can be replaced by rolled mild steel—three times stronger, twice as rigid and much cheaper ; how mild steel, arc welded, can assume forms into which no amount of ingenuity could torture cast iron or steel.

This new freedom enables the manufacturer to constantly improve his design for best possible competetive advantages.

The film compares various materials and it presents a study of load factors, stresses, rigidity, performance and appearance. It explains how welded design can be used to speed up fabrication, reduce weight and obtain greater strength and rigidity from less material.

Technical Institutions, Engineering Firms, and any other concerns interested in the process are invited to apply for the loan of this film free of cost, for showing to their staffs.



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ENGLISH STEEL CORPORATION LTD.

The English Steel Corporation Ltd. has arranged a press tour to afford facilities for inspecting recent extensions to their Small Tools factory at Openshaw, Manchester. 62,000 sq. ft. of floor space has been allocated for the manufacture of Twist Drills and a Finished Tool Stockroom, and an entirely new type of layout has been completed and is in full operation.

Standard and special length taper shank and straight shank high speed steel drills, 3 and 4 flute core drills, centre drills and jig boring drills of finest quality, can be produced in the new section at an overall average rate of approximately 1,500 per hour.

The plant consists of machine tools of the most modern design ; automatic and semi-automatic machines are employed where practicable. Modern equipment in use includes a bank of the very latest type of Cincinnati Flute Milling Machines, each capable of milling three drill flutes at one setting on an automatic cycle, machines for tang milling embodying the use of a constantly rotating table, magazine fed grooving machines, semi-automatic straight shank heat treating machines and a modern Eddy Current Set for brazing small size drills into morse taper shanks.

The new extension impresses by its spaciousness and its air of cleanliness and tidiness, and the workpeople are obviously proud of their shop and the work they do.

CORROSION OF IRON AND STEEL BY INDUSTRIAL WATERS AND ITS PREVENTION

Special Report No. 41 *of The Iron & Steel Institute.* (56 pages, 24 illustrations.)

THE subject of corrosion is so complex that the average engineer is inclined to put his trust in " hit or miss " methods rather than in an analysis of possible causes and methods of prevention. The present brochure issued by the Industrial Waters (Corrosion) Sub-committee is based on a thorough review of existing data on the subject and surveys, in a general manner, existing knowledge of the corrosion of iron and steel by industrial waters and of the preventive measures which might be employed. The booklet is, at the same time, short, clearly arranged, and comprehensive, and can be recommended, as a survey of the subject or as an introduction to more thorough investigation or as a " first-aid " book for immediate analysis and preventive measures. A list of reference books and of many important papers published since 1927 adds to its great value.

ATLAS OF ISOTHERMAL TRANSFORMATION DIAGRAMS OF BS. 970 EN STEELS

Special Report No. 40 *of The Iron & Steel Institute.* (15 pages introductory text, 11 illustrations, 24 diagrams.)

THE advantages of isothermal heat treatment of steels, e.g., the reduction of annealing time or the avoidance of heat cracks on rapid cooling, are well known. However, a wider application of these methods has been hampered by insufficient knowledge and want of readily accessible presentation of data as to the behaviour of the most widely used constructional steels. The present atlas gives diagrams of 24 representative commonly used steels with a condensed explanatory foreword, and thus fills a gap which, for some time now, has been very obvious. It should enable not only the metallurgist but also the mechanical engineer and designer to use these new methods with some confidence. Although the exact behaviour during isothermal transformations of a steel at hand depends on many, not readily assessable, contributing factors, the atlas provides a basis for appreciating the behaviour of steels when annealed or quenched in sections which do not harden completely.

British-Made Thermocouple Alloys. After research within their own organisation and in industry, the British Driver-Harris Company have now succeeded in producing two new thermocouple alloys for high temperature measurement. These products, T1 (nickel-chromium) and T2 (nickel-aluminium), are similar to those, widely used in industry for many years, of materials imported principally from dollar sources. The British Driver-Harris T1 and T2 alloys, however, are manufactured throughout at the Company's factories at Manchester and Cheadle Heath. There has been no increase in the price of these two alloys due to the recent devaluation of sterling.

We understand that these new British-made alloys will operate at the same temperatures as those usually covered by similar imported materials, the thermal E.M.F. values following the same general curve.

The Nickel Bulletin. The October issue is devoted entirely to abstracts from recently published material.

The variety of subject matter is seen in the brief selection given below :—

Induction Brazing of Nickel Alloy Permanent Magnets
Spot Tests for Nickel Alloy Steels
Nickel-containing Materials vs. Sterilizing Solutions
Iron in Cupro-nickel Condenser Tube Alloys.

Copies of The Nickel Bulletin may be obtained free of charge on application to The Mond Nickel Company, Ltd., Sunderland House, Curzon Street, London, W.1.

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METROPOLITAN WATER BOARD.
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(2) ENGINEERING ASSISTANTS—Salary scale £395 rising to £510 p.a.

A cost-of-living bonus, now £80 per annum, is payable in addition to the above. Commencing salaries according to age, qualifications and experience. The age limits for (1) above are 30-45 years.

Candidates for appointment must be corporate members of the Institution of Civil Engineers, have had a good practical training, and experience in the design and/or construction of civil engineering works. Waterworks experience desirable but not essential.

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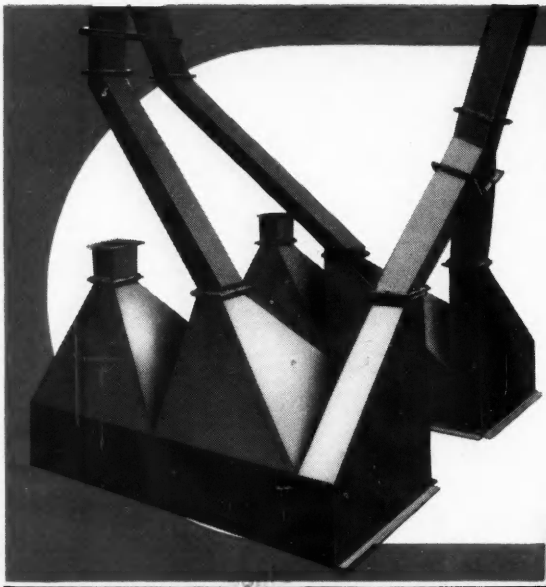

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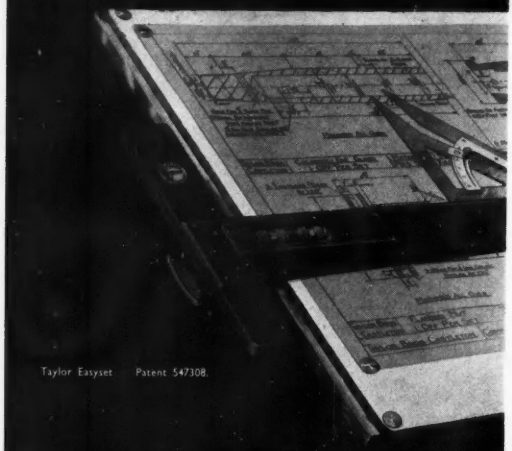

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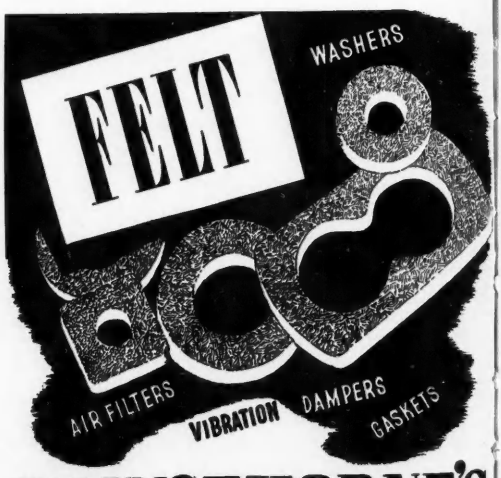

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THE ENGINEERS' DIGEST

REVIEW OF WORLD ENGINEERING PROGRESS

VOL. X. No. 12 DECEMBER, 1949

IN THIS ISSUE

METALS deform by slip of atomic planes within the single-crystal grains, and this slip process is not instantaneous but requires a certain amount of time, though this is very small. In some dynamic applications, we may approach this time limit, and an investigation of the influence of different variables by impact testing may become imperative. For a given material, these variables can be grouped under the general headings of stress concentration, speed of testing, and test temperature. The authors of our abstract* on page 412 introduce the notion of stress concentration ratios (ratios of the three principal stresses) and show that the influence of stress concentrations can only be found from impact tests on specimens of different width, but, otherwise, of identical shape. Test results then show a complete qualitative analogy of the three interdependent variables, and the authors are able to draw the very important conclusion that a material can be regarded as safe against brittle fracture as long as a small increase in only one of the three variables leads to an increase in specific impact rupturing energy. There obviously remains the considerable difficulty of estimating the severity of stress concentrations in any given practical case, but at least the service temperatures and speeds of impacting forces can be foreseen to a certain extent, and materials chosen correspondingly, so that maximum safety against the stress concentration effect is obtained. A general consideration of the influence of stress concentrations finally leads the authors to a new interpretation of the well-known phenomenon of "necking" during tensile tests.

* * *

When the second World War began, the application of electronics to industry was already ten years old. Since then, the staggering demands made on industry have forced manufacturers to operate with little or no margin of spare capacity and to expand their plant facilities as rapidly as materials became available.

Electronic control is one of several important tools for the steel engineer to use in boosting output and reducing cost. It is nothing more than a tool. In itself, it is not the push-button plant of tomorrow nor the cure for production men's occupational diseases. On the other hand, it is nothing less than a tool. Its worth to industry has been proved over and over again, and today electronics has a definite part to play in effecting very appreciable savings in material and labour and in improving the quality of the product into the bargain.

The advice of nine or ten years ago still holds good today. Electronics is applicable to industry to fulfil either or both of two requirements. Just as there should be no hesitation about utilizing it to the full for either of these, there should also be no consideration of its use whenever it fails to meet these requirements. It should be used where it operates in a manner which is not possible with other available equipment and where its superior response, speed and sensitivity as compared with more traditional equipment are required; or alternatively, it should be used where its cost and complexity for an equal job are less.

We extend to all readers our best wishes for a Happy Xmas and a Prosperous New Year.

The finest piece of industrial electronic equipment in the world is useless if it is not properly applied. The engineer applying it cannot know too many details about the associated gear and the requirements of the overall process. There is no advantage in using an induction flow brightener equipment on an electrolytic tinning line in order that the line may be speeded up, if the remainder of the installed equipment is already working at its maximum speed and capacity. Proper application and co-ordination of electronic control, see our article on page 417, automatically means increased tonnage, better quality or reduced costs, or a combination of these.

* * *

The position in Sweden regarding hydroelectric power is characterized by long transmission lines owing to the northerly situation of the major water resources, while consumer centres are located mainly in Central and South Sweden. As more power becomes available with the completion of projected power schemes, some in the near future, the existing 220-kV transmission system will no longer be adequate and must, therefore, be supplemented by 380-kV lines of considerably greater power capacity. The article on page 419 deals with the 380-kV system in its initial stage of development with special reference to the problems arising from the high system voltage.

*The first instalment of this article was published in our October issue, pp. 350-354.

FRANCE

Influence of Stress Concentration, Speed of Deformation, and Temperature on the Rupturing Strength of Steels.

By A. GUEUSSIER and R. CASTRO. From *Revue de Métallurgie*, Vol. 46, No. 8, August, 1949, pp. 517-536, 22 illustrations.)

(*Continued from October issue.*)

III. THE LAWS OF PLASTIC DEFORMATION.

A MATERIAL stressed beyond the elastic limit may either deform plastically by slip or break without deformation by cohesion failure [4]. Under otherwise constant test conditions, an increase in any one of the three embrittlement "factors" (test speed, reciprocal of the absolute test temperature, triaxial stress ratios) increases the resistance of a material against elastic deformation and, for a given amount of deformation, also the resistance against plastic deformation [6, 7, 8]. The resistance against slip is thus increased as compared with the resistance against cohesion failure. The tests described in this paper show that the specific energy of deformation, when measured under comparable conditions, first increases and then decreases more or less rapidly with any further increase in any one of the embrittlement factors; in other words, the resistance against slip increases until brittle fracture by cohesion failure becomes prevalent. The transition interval from ductile to brittle failure occurs when the embrittlement factors reach certain critical combined values characteristic of each material, and is indicated by the drop in resilience values. If either the triaxial ratio or the test speed is increased, the drop in resilience values will occur at higher temperatures [9]. If the temperature or the speed is increased, the drop will occur at higher values of the triaxial stress ratios. The close analogy of the effect of the three embrittlement factors is thus apparent and the following general rules can be formulated :—

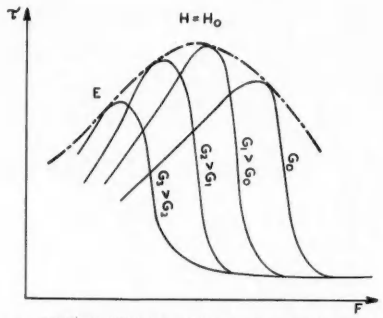
In impact tests under given conditions, the specific work done in fracturing a specimen of a cubic metal can be measured as a function of the triaxial stress ratios, the test speed, and the test temperature. Let F, G, H be the three test variables, then

(a) if G and H be constant, the specific work done in fracturing the specimen increases with increasing value of F, passes through a maximum, and then drops more or less suddenly as the transition interval from ductile to brittle fracture is reached (Curve G_0, Fig. 10),

(b) if H only be constant, the maximum and the transition zone are displaced towards lower values of F as G increases. The envelope E of the series of curves taken with various constant values of G has itself a maximum which represents the maximum specific work obtainable for a given value $H = H_1$ (Fig. 10),

(c) as H is also varied, a series of envelopes E is obtained and the absolute maximum of all E-curves represents the maximum possible specific rupturing energy of the tested material under any conditions. The factors F, G, H for which this absolute maximum is reached can be considered as *intrinsic qualities* of the tested material.

The transition zone is a danger zone to be avoided because a slight change in test conditions may decisively upset results obtained in this zone. For each material, we should, therefore, know the change of resilience with the change in each of the three embrittlement factors, and the otherwise rather empirical impact tests in bending and tension allow of finding these relationships. Impact tests are safety tests ensuring that the behaviour of the metal really conforms to the conditions on which stress calculations are based. The absolute value of the resilience is not the most important conclusion to be drawn from these tests, but a knowledge



τ = SPECIFIC WORK OF DEFORMATION UP TO FRACTURE, F AND G = VARIABLE FACTORS OF EMBRITTLEMENT

Fig. 10.

can be obtained of the existing safety margin between service conditions and onset of the transition zone. Since service speed and temperature are usually known and only the triaxial state of stress may vary in an unknown manner with faults in the material and variations in cross-section, the material should be so chosen that, for the given service conditions, the transition interval is reached at the highest attainable values of the triaxial stress factor. It is always advisable to keep on the safe side of the maximum resilience test values, and we may, therefore, draw the general conclusion that *a material is safe for certain proposed service conditions if, for the worst imaginable values of service speed, temperature, and triaxial stress ratios, a slight increase in any one of these embrittlement factors leads to an increase in the rupturing energy of the material.*

IV. A NEW INTERPRETATION OF THE NECKING PHENOMENON.

According to Ludwik's theory [10], a maximum shear stress and a maximum direct stress exist at any point of a material stressed under given conditions of temperature, test speed, and triaxial ratios. The shear stress is supported by the resistance of the material against slip, i.e., against plastic deformation, and the direct stress by resistance against cohesion failure, i.e., against rupture without deformation. Plastic deformation of the metal will start when, and continue as long as, the shear stresses reach the critical shear stress value before the direct stresses attain cohesion strength value. With the load—deflection (or true stress—natural strain) curve of a tensile test, we can, therefore, associate another curve representing the cohesive strength of the metal under test conditions. The deflection curve lies entirely below this curve for the cohesion strength, but reaches it at the point of final fracture, i.e., of cohesion rupture. The exact shape of the curve of cohesion strength is not known. Neither the deflection curve nor the cohesive-strength curve represents intrinsic qualities of the metal, but they depend on the three parameters, speed, temperature, and triaxial stress ratios [7, 11]. For a theoretically exact investigation, the variation of these curves with a change in any one of the three parameters ought to be known. A first idea can be obtained if the points of intersection of the two curves, i.e., the points of final rupture, are plotted for various test conditions.

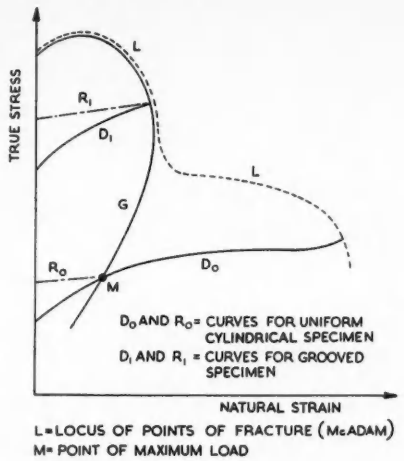


Fig. 11.

Fig. 11 represents schematically the type of curves L thus obtained by McAdam.

The deflection curve of the simple tensile test on grooved or uniform cylindrical specimens shows an elastic range OA (Fig. 12), a range of uniform plastic extension AB up to the point of maximum load B, and a range BC of localised extension (necking) leading to fracture at C. According to Ludwik, the curve R of cohesive strength would lie above the deflection curve D and join it at point C only. The authors, however, consider that the triaxial state of stress changes fundamentally during the localised extension BC and that during this change, the resistance against slip and the resistance against cohesion failure change in identical fashion. The curves D and R should, therefore, join at the point of maximum load B. (See Fig. 12). At point C, the possibilities of plastic flow of the metal are exhausted and the specimen must break by cohesion failure. The energy of deformation of this localised extension becomes less important as the total test length increases and it can be neglected if the test length is very large. With a grooved specimen, the total test length is very small and it can reasonably be assumed that the doubly localised extension becomes infinitesimal. Points B and C then practically coincide and curves D and R, in fact, intersect at point C.

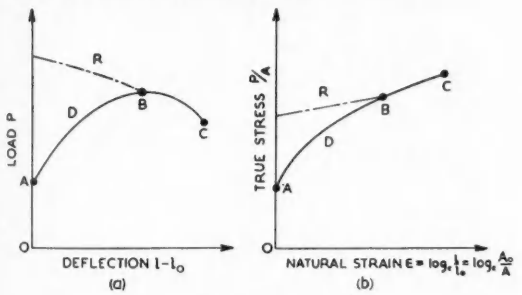


Fig. 12a and b.

The investigations conducted by McAdam and other scientists into the point of fracture under varying conditions of triaxial stress and test temperature, therefore, combine phenomena that are not rationally comparable. Only the uniform deformation ending at the point of maximum load takes place under well defined conditions. Not the actual points of fracture (Curve L, Fig. 11) but the points of maximum load (Curve G, Fig. 11) indicate the intersection of the curve of cohesive strength R with the deflection curve D. Curves L and G coincide for tests ending in fracture without localised necking, but deviate from each other in tests where localised deformation has taken place. Figs. 13 and 14 have been taken from papers by McAdam [7] and curves G connecting the points of maximum load have been traced into them. These curves represent the points of maximum ductility of the specimens under varying conditions of temperature and triaxial stress ratios. Beyond this maximum, the ductility falls more or less rapidly towards zero as it does in the transition zone to brittle fracture. Thus, we again find the maximum of the specific work of deformation up to fracture and the transition zone if any one of the embrittlement factors is increased. The similar form of the G-curves in tests

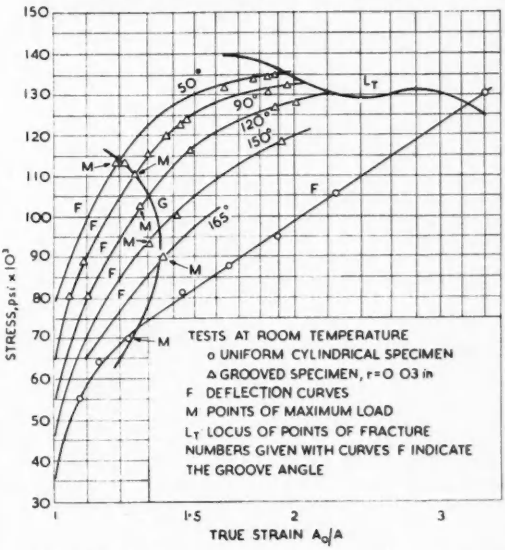


Fig. 13. **Influence of groove angle on tensile stress-strain curves.** (From the paper by D. J. McAdam, Jr.).

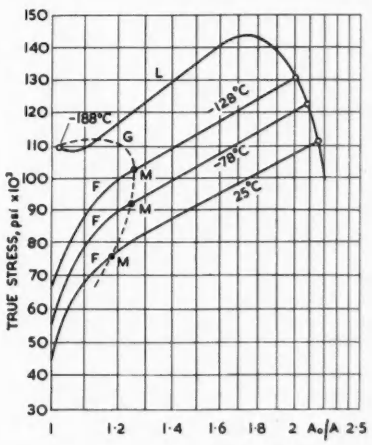


Fig. 14. **Tensile tests on annealed 0·11 per cent carbon steel.** (From the paper of D. J. McAdam, Jr.).
The numbers given with Curves F indicate the test temperature.

with varying triaxial states of stress, with varying temperatures (Figs. 13, 14), as also with varying test speeds (deduced from Hoppmann's tests) confirms the close analogy of the effects of the three embrittlement factors.

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GERMANY

A New Hydraulic Torque Amplifier

By H. Wilcke. (From *VDI-Zeitschrift*, Vol. 91, No. 5, March, 1949, p. 115, 2 illustrations.)

A torque amplifier is an element of a transmission system which enables an arbitrary amount of power to be introduced into a system without changing its angular velocity. Essentially it consists of an input shaft and a power source or motor provided with an output shaft. The input governs the motor speed. The torque required from the input (which is determined by the motor design) should be small and independent of the load on the output shaft. Both shafts are to run at the same speed under all conditions, but the output shaft may suffer a phase displacement relative to the input shaft, the magnitude of which depends on the load. Up to now, both mechanical and electrical torque amplifiers have been in use.

The new hydraulic amplifier consists of a high-pressure hydraulic motor (with oil as working medium) combined with a flow regulator which acts as governor. The regulator acts as a stop-cock, cutting off the oil flow when the motor exceeds the input speed, and increasing the oil flow when the motor speed is too low. In practice, this action is obtained from two well-fitting sleeve valves, both of which are free to rotate in the amplifier housing, the governor sleeve being part of the input shaft while the follower sleeve is fixed to the output shaft.

Operation is as follows, both shafts being initially at rest. When the input shaft starts up, the governor sleeve opens a path for the high-pressure oil to actuate the motor; thus, the motor starts up and the follower sleeve moves in step with the input shaft, and maintains the port opening appropriate to the load. If the angular velocity of the input shaft increases (or if the output shaft lags due to an increase of load), the port opening increases and more power becomes available, bringing the motor into step.

If the input shaft stops, the motor continues to run until the port is closed. As a result, the oil flow (and with it the power supply) is cut off. Moreover, in the present design, a braking moment is obtained when the regulator is closed. It is clear that the lag between the input and output shafts is equal to the angular opening of the regulator ports, which in the present design is only a few degrees at maximum load. Solid stops prevent the device from being thrown out of step by overloads, shock loads, etc. Designs are available for use in either direction or in both directions. The speed of revolution can be varied to the extent of about 1:100 or more. The output torque may be designed from 10 to 1000 mkg or more.

The hydraulic motor operates at around 1400 psi and is designed so that its angular velocity and its torque on constant port opening do not vary with the angular position of the output shaft.

The radial cylinder block *b* (see Fig. 1) rotates on valve journal *a*, which is fixed to the housing and provided with inlet ports *f* and oil return slots *g*. To the cylinder block are fixed both the output shaft and the follower sleeve *h*. It also carries the pistons *c* and their actuating rollers *e*, which follow cam plate *d* (which is fixed to the housing). Arranged concentrically with journal *a* is the regulator consisting of governor sleeve *i* and follower sleeve *h*.

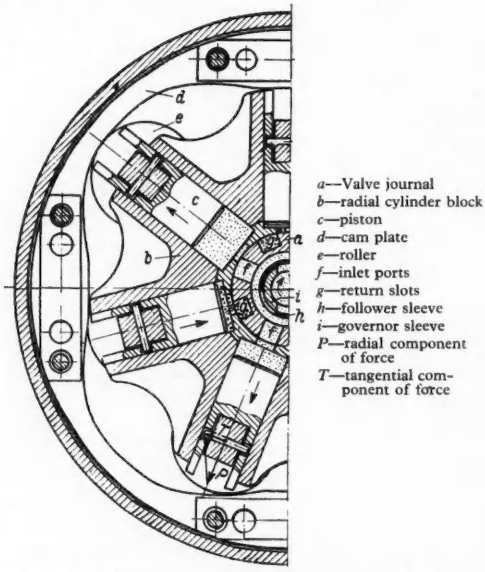

Fig. 1. **Radial section through hydraulic torque amplifier.**

When the input shaft rotates and there is an opening between *i* and *h*, the high-pressure oil is forced into the reservoir between *h* and *a* and into the ports *f*. Wherever there is a cylinder opposite one of the ports, the oil pressure is exerted on piston *c* and roller *e*. Now opposite the ports, the curve of cam plate *d* slopes away from the centre of the housing, so that the reaction normal to *d* has a tangential component *T* as well as the radial component *P* which is due to the oil pressure. The force *T* causes torque and consequent rotation of the output shafts. This rotation causes closing of the port *f* of the cylinder considered (and opening of one or more of the other ports) while roller *e* now traverses a concentric portion of cam plate *d*. When

this cylinder reaches one of the oil return slots *g*, roller *e* and piston *c* are pressed in by a portion of cam plate *d* which approaches the centre of the housing, so that oil is emptied from the cylinder. When this port is passed, another concentric portion of *d* is traversed, after which further power and return strokes alternate.

These motors are arranged for 1 to 6 power strokes per piston and for revolution according to the desired speed range.

Torque amplifiers are mainly used in automatic instruments of various kinds, but are also applied to the governing of special machines and devices, in which the speed is varied by computing gear boxes or depends on other machines, and where rigid drives are objectionable for one reason or another.

A good example of this type of application is the drive of veneer-cutting machines. In this case, the delivery speed of the veneer has to be related to the speed of the next machine in the process line. This machine drives a governor shaft, which enters a computing gear also acted on by a feeler which determines the instantaneous diameter of the log being cut. The result of the automatic computation is fed to the input shaft of a torque amplifier, so that sufficiently delicate gears can be used in the computing gear box while still obtaining a reliable final drive of ample power.

CZECHOSLOVAKIA

Mechanical Stoker with Bottom Ignition

By E. Dvorak. (From *Elektrotechnicky Obzor*, Vol. 38, No. 6-7, April, 1949, pp. 186-188, 2 illustrations.)

The efficiency of stokers using fuel of high moisture or ash content is low. The reactivity, the reactive fuel surface, the temperature of burning, and the aerodynamic influences on the air, are less favourable than with good quality coal.

The area of the reactive fuel surface is diminished by late ignition, causing a lowering of both the temperature in the combustion space and the specific output of the stoker. Most mechanical stokers ignite from the top, or backwards. The most efficient method, however, ignites the fuel from below. This article describes the author's method of ignition of the fuel from below with hot air.

The author carried out a number of ignition experiments with air fed from below, at 300-400° C. He obtained a high specific output, without excess air, under carefully-chosen conditions. Brown coal became ignited already at a temperature of 180° C, the ignition, of course, being slow. The ignition is speeded up by an increase in the air speed and temperature. There is, however, an upper limit to an efficient temperature increase.

The outcome of these experiments was the design of an auxiliary grate to the stoker, which applies ignition from below. The hot gases arising from the burning of the lower layers of the fuel are drawn against the direction of the fuel feed. The bottom layers of the fuel will be of coarser size and their advance will be slower than the top layer.

Fig. 1 shows schematically the principle of a grate of this kind for use in front of a mechanical stoker. The fuel is sorted according to size in the drum *B*, whence it falls into the container N_1, which is filled with coarse and medium size coal, and into the container N_2, the latter being filled with fine grain. The coarse fuel from N_1 slides onto the grate, consisting of five steps, S_1 to S_5. S_1, S_3 and S_4 are moving parts, their travel being dependent on the movement of the mechanical stoker. The travel of S_1 and S_3 is comparatively small, their object being to move the bottom layer of the fuel, where ignition sets in. The main purpose of the step S_4 is to move the fuel on to the mechanical stoker, and thus regulate the fuel depth on the grate. The fine-grained fuel is fed from the container N_2 on to the top of the coarse fuel, its depth being regulated by the gate *H*. It is advantageous that the speeds of the coarse and fine coal can be relatively varied for optimum efficiency.

There are several ways of using this auxiliary grate. The ignition from below will be most efficient if the hot firing gases from the region of the steps S_1 and S_2 are drawn through *L* into the space *O*. This is done by lowering the pressure in the space *O*. The curve r_1 in Fig. 1 shows the boundary of the region from which the gases are drawn for ignition along the arrows 1. When the pressure in *O* is further decreased, the boundary curve moves into the position r_2. The ignition gases will flow in this case along the arrows 1′. The arrows 3′ indicate in this case the direction of flow of those firing gases which enter the firing space and are not used for ignition.

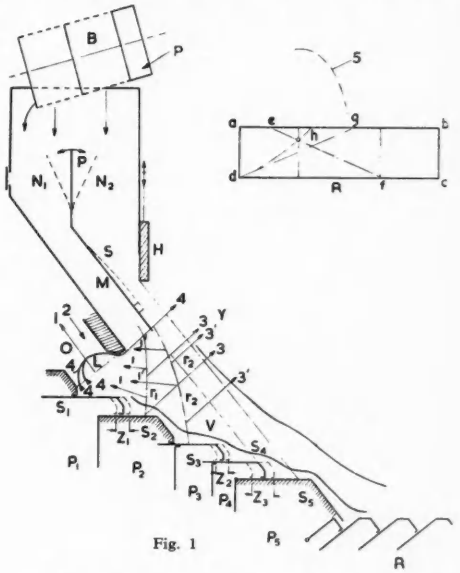

Fig. 1

It is obvious from Fig. 1 that the fuel and the hot gases move in opposite directions, resulting in optimum conditions for ignition. As the hot igniting gases contain a considerable proportion of unburned gases, additional air will be required for the space *O*. The air speed in the bottom layers will be high, as the fuel is coarse and, therefore, the ignition will be more rapid. The burning layer of fuel will quickly increase in thickness. The quantity of burning fuel can be easily regulated by varying the speed of the moving steps and by regulating the air-flow. The fuel delivered to the mechanical stoker *R* will be alight in the bottom layers, thoroughly dried in the middle layers, and probably ignited on top.

The output of this type of grate is estimated to be nearly 400,000 B.Th.U/sq ft per hour when igniting wet lignite.

The small sketch in the top right-hand corner of

Fig. 1 explains schematically the burning conditions on the grate. The rectangle *abcd* indicates the layer of fuel. The ignition from above affects the fuel to the right of the line *ef*. The ignition from below will be faster and the corresponding ignition boundary will be *dh*. In consequence, the whole fuel layer will be burning from the point *h* to the right, when ignition from below is applied. The specific output of the grate is increased in proportion to the areas $\frac{ebcdh}{ebcf}$; therefore, the depth of the fuel layer can be increased.

This auxiliary grate considerably increases the output of the boiler plant, and as it can be easily regulated, high efficiencies are reached for varying loads. The fact that large quantities of unburned gases pass into the combustion space is no disadvantage, as complete combustion can be attained by the correct supply of additional air. As gases are burnt in this case, very little excess air is required.

The grate is very well suited for fuels of very high moisture and ash content.

U.S.A.

New Grid Casting Improves Battery Life

By E. WILLIHNGANZ. (From *The Iron Age*, Vol. 163, No. 23, June 9, 1949, pp. 62-65, 6 illustrations.)

A NEW type of lead grid for supporting the active oxides in the positive plates of lead-acid storage batteries has been developed by the Gould Storage Battery Corporation, of Depew, N.Y. The grid is the result of extensive research in lead-casting techniques and grid design, and it is expected that it will lead to substantial increases in service life of industrial storage batteries.

Ninety per cent of all motive power battery troubles to-day are due to the failure of metallic lead members in positive grids. Grid failure almost invariably occurs where voids and porosities have permitted the acid to peroxidize grid members from the inside. The problem was, therefore, to develop a technique which would eliminate shrinkage porosity in the gravity casting of the antimonial leads used for battery grids.

Two types of shrinkage porosity occur: (1) *simple cavities or pipes*, which are formed by solidification shrinkage of liquid masses completely encased in solid envelopes of previously frozen metal; (2) *intergranular porosity*, appearing as a general mushiness in the casting, which can develop when the pure lead phase freezes too quickly (at 630° F) while the remaining antimonial phase stays liquid and concentrates to the 12 per cent eutectic, then freezing out at a lower melting point (477° F). The porosity may extend to the surface of the casting where acid can then easily get at the pore system.

To reduce shrinkage porosity, controlled and progressive solidification is required, and this depends primarily on casting technique and grid design.

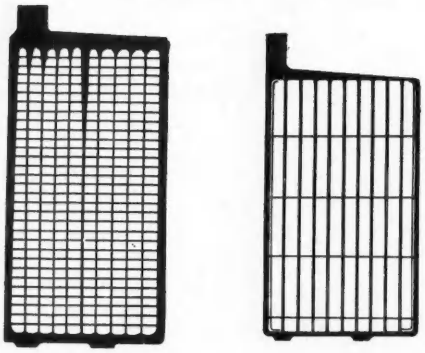

Fig. 1. **Comparison of a new type grid** (right) **and a previous design** (left), **used for batteries of comparable capacity.**

CASTING TECHNIQUE

With the new technique, the gating into the mould is through much smaller openings than usual, so that the rate of flow of metal is reduced. The casing temperature is higher to avoid uncontrolled freezing. The pouring of the new grids is wholly from the top lug so that no shearing of the sides or ends of the grid frame is necessary. Side and bottom shearing frequently discloses edge porosity, and also produces sharp edges which cut through battery insulation and separators. In the latest type grids, shown in Fig. 1, the as-cast edges are rounded off.

The grid is produced in a mould with controlled heat-transfer rates at various points, the freezing of the metal beginning at a predetermined point and proceeding slowly and evenly throughout the entire grid mass. A new type of hydraulically operated and air-cooled casting machine is used. The mould is finned externally and cooled by air blast at specific points. Mould coating compounds with appropriate heat insulating characteristics are used. Ample overflow zones are provided above the small gate openings, so that any pipes occuring at the end of the freezing process will be in the useless remelt stub above the gate.

GRID DESIGN

The new Gould " Z " grid, shown in Fig. 1, is of extremely simple design. It is characterized by unusually large areas of unsupported cells of active material, and has vertical and horizontal members of identical, diamond-shaped cross-section. These features were adopted because: (1) porosity due to different freezing rates particularly tends to occur at the junctures of fine and heavy members; (2) porosity occurs more frequently in members with a large ratio of mould surface to enclosed metal; (3) the diamond cross-section exposes a minimum of lead surface to direct contact with the acid electrolyte in the assembled battery, and gives a sufficiently rigid structure. The new type grid members are designed with a Vee notching which securely grips each enclosed pellet of active oxide on all sides.

The electrical capacity of the new grids permits these to be made shorter than grids of the old type, for the same ampere-hour capacity. Thus, more space is available over grid tops, and this allows greater latitude in electrolyte level in existing standardized battery jar designs.

Microscopic examination of fractured test specimens exposed to acid attack has indicated that with the new type grids, porosity can be reduced from 85 to 90 per cent. This should in itself constitute a major step forward in battery grid improvement.

Application of Electronics in the Iron and Steel Industry

By W. M. McKie and D. A. Lamont. (From *Iron and Steel Engineer*, Vol. 26, No. 8, August, 1949, pp. 59-67, 14 illustrations.)

Electronic devices, especially developed for steel mill use, are finding widespread acceptance. Electronic control is a new tool in the hands of the industry, and its adaptability, superior response and sensitivity have enabled very appreciable savings to be made in material and labour, while also improving the quality of the product.

Industrial type equipment is more rugged than its laboratory counterparts. The tendency is to rely less on the tube characteristics and more on those of the other circuit components. Increased dependability is obtained by making greater use of single-purpose tubes, and more tubes per equipment. In the following lines a brief description will be given of seven particularly interesting types of equipment developed in recent years.

ELECTRONIC MOTOR CONTROL

The inherent ability of d.c. motors to allow a greater variety of speed-torque characteristics and their greater ease of control are well known. Their use, however, has been limited by the necessity of providing rotating conversion equipment for operation from a.c. sources. The efficient sealed-ignitron rectifiers and sensitive controls now available make the use of these motors far more attractive. The equipment has characteristics similar to those of the conventional adjustable voltage system, but is not adapted for rapid reversal. Two or more motors may be connected to a single electronic d.c. drive.

The main unit is a six-tube two-way rectifier circuit converting three-phase 460-volt a.c. to 550-volt d.c. Three sizes of tubes are available to cover the 100 to 600 hp range of drives. The d.c. voltage is continuously adjustable by phase control of the ignitor excitation. With a 460-volt supply a rectifier transformer and an air-core current-limiting reactor are used. For a supply between 480-575 volts, an auto-transformer is employed, while for medium or high voltage supplies (from 2300 to 15,000 volts) a standard three-phase power transformer is required. This usually has sufficient reactance for rectifier protection, so that current-limiting reactors are unnecessary.

The standard d.c. motors are used without the derating for heating and reduced commutating capacity occurring when motors are operated from single-phase supply. The excitation equipment and the magnetically-saturable phase-shifter consist entirely of static devices, and arc ignition of the ignitrons is phase-controlled so that the rectifier output voltage is fully adjustable according to requirements for starting, accelerating and decelerating the drive motor. Automatic control of the saturating current for the excitation system is usually provided by a rotating regulator, and speed regulation to one or two per cent is easily achieved.

The motor field current is automatically maintained at a constant adjustable value by a thyratron rectifier. The field rectifier controls the rate of field current increase in response to a signal obtained from armature voltage, this feature being necessary for high-inertia loads, and in addition, armature voltage take-over control is used in certain cases. For rapid retardation, a dynamic brake resistor and a contactor are employed to absorb the regenerated energy of the motor.

As a rectifier operating at a reduced, i.e. phase-shifted, voltage has a reduced power factor, it is an advantage in some cases to use a large motor frame and operate in the field control range except for jogging or threading which are at reduced voltage. Drive reversal is possible by means of contactors for field connection reversal or alternatively by installing a duplicate rectifier unit.

ELECTRONIC POWER CONVERSION

The Edgar Thomson Works of the Carnegie-Illinois Steel Corporation have had two 10,000-kW electronic frequency changers in service since the beginning of 1944. The pentode sealed-type ignitrons had a 3-year warranty, and after a fourth year of service, over 50 per cent of the tubes were still functioning correctly. Even on the basis of a 3-year life, the higher efficiency over the whole operating range of the electronic frequency changer compared with rotating converters, more than pays for tube renewals.

The electronic frequency changer is used for controlling power flow between systems having the same or different steady or variable frequencies and voltages. The conditions for optimum efficiency are that (1) sufficient reactive kVA are available for commutation, harmonics, and transformer magnetizing current, from synchronous machinery of both interconnected systems ; and (2) the system voltages should be sufficiently high to require the transformers necessary in the electronic changer, for a.c. and d.c. circuit insulation. For cases outside this sphere, conventional equipment should be chosen.

The direction and magnitude of power flow is controlled by varying the rectifier and inverter grid excitation by phase-shifting. Controls can be provided which are responsive to predetermined ratios of power supplied by other prime sources of either system, etc. Fault currents cannot be contributed by the converter to a fault in the system supplying the rectifier end of the converter, and a fault current from the converter to a fault in the inverter-supplied system is limited by the inverter commutation characteristic to slightly more than full-load current. Internal faults such as arc-backs in the rectifiers and failure of an inverter to resume control during positive half cycles are suppressed by high-speed relays and contactors which bias the rectifier grids and reduce rectifier currents to zero until the defective circuit operates satisfactorily. A typical diagram of an electronic frequency-changer is shown in Fig. 1.

X-RAY THICKNESS GAUGE

Increased speed and production have been obtained with a new X-ray thickness gauge* operating on a hot strip mill in the Irvin Works of the Carnegie-Illinois Steel Corporation. The equipment is readily adaptable for all gauging work where a non-contacting gauge is required.

Prior to its advent, the hot strip was gauged using a hand micrometer at one end of the strip coil, and then only after the metal had cooled considerably. With strip speeds of 2000 fpm and temperatures of 1300-1750° F, something like 6 tons of steel may be rolled before gauging is possible by the old method, so that heavy losses due to reallocation of off-gauge strips might be expected. Additional difficulties were presented by the cooling water sprays and the vertical vibration of several inches of the strip as it leaves the rolls, which makes large clearances necessary to avoid jamming.

The new X-ray thickness gauge has an overall accuracy of ±2 per cent over the range of 40-190 mm of steel thickness. A zero adjustment is provided for use with the various scales on the gauges required for measuring different alloys. The equipment comprises an

*See also The Engineers' Digest, June, 1948, pp. 194-196.

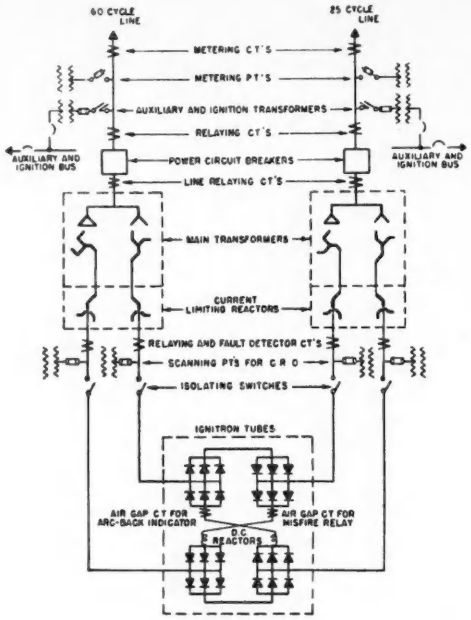

Fig. 1. **Typical single-line diagram of an electronic frequency changer.**

X-ray tank unit, a top detector head, a control cabinet, a gauge dial, and at least one deviation dial. A 100-kilovolt tube is used for hot steel, and a 50-kV tube for cold steel or aluminium. Cooling of the X-ray tube and its H.T. and filament voltage supplies is by forced oil circulation.

The X-ray tube transmits two beams at right angles. The horizontal reference beam passes through a steel gauge wedge, which can be adjusted by a small reversible motor controlled from the operator's desk so as to place a desired thickness of steel in the path of the beam. The transmitted radiation falls on a detector unit consisting of a photocell with a zinc sulphide fluorescent coating and a glow-discharge lamp. The glow of the fluorescent coating during positive half-cycles is picked up by the photocell and compared with the light from the glow-discharge lamp radiated during the negative half-cycles, and any difference voltage is then transmitted to the automatic H.T. control system. The regulator maintains constant energy at the fluorescent coating when the position of the gauge wedge is varied by the operator.

The second beam passes vertically upward through a second adjustable steel deviation wedge, and through the thickness of the strip to be measured. The rays make a one-inch wide trace on the moving strip and fall on the overhead radiation detector, also consisting of a photocell with a fluorescent coating and a glow-discharge lamp. The difference voltage of this circuit causes an automatic positioning system to readjust the deviation wedge until the difference is zero, and the difference in strip thickness is indicated on the deviation dial marked in millimetres.

SUPERSENSITIVE PIN-HOLE DETECTOR

This new equipment detects pin-holes as small as 0·005 in. in diameter at strip speeds of 50-1000 fpm. The previous pin-hole detector could only indicate pin-holes at least three times this diameter, and only up to 900 fpm.

The new scanner comprises a light unit with two cylindrical condenser lenses extending the full 40 in. of strip width. The light is supplied by 31 cinema type photocell exciter lamps with straight filaments, and is focussed on the strip surface. Light passing through a pin-hole will fall upon a photocell after passing through a diffusing opal glass window. The detector is provided with a pair of adjustable shutters to shield the end photocells when operating on strips narrower than 40 in. Floating shutters can also be installed so as to follow any lateral movement of the tin plate by means of rollers riding against the strip edges. Thus pin-holes can be detected to within $\frac{1}{8}$ in. of either edge of the strip. A sketch of the new scanner unit is given in Fig. 2.

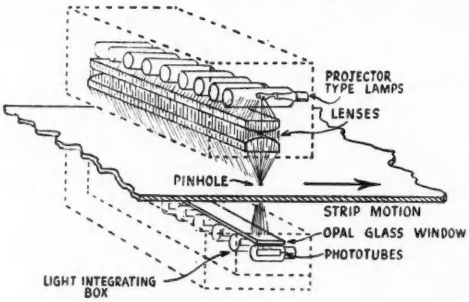

Fig. 2. **New supersensitive pin-hole detector.**

The photocell voltage is fed to an electronic timer on a control panel. This timer delays operation of a marking device until the pinhole has moved to a position adjacent to the marker. The control panel also initiates the operation of the diverter gate which allows the cut sheet containing the pin-hole to be rejected.

SYNTHETIC CURRENT TOTALIZER

In order to be able to correlate properly the speed with the plating current, the operator of a tinning line should be able to read the total current. Instead of using a heavy, power-consuming bus bar from each current rectifier or generator section along the plating line and a large expensive shunt, the synthetic current totalizer totalizes the plating currents without bringing the actual circuits together.

Equipment of this type has been installed in the Aliquippa Works of the Jones and Laughlin Steel Corporation. An average value representing the total current is obtained by combining the indications from a number of 50-100 millivolt shunts in each plating rectifier or generator section. The output is applied to a coil of an industrial type galvanometer, and the deflection of the galvanometer mirror brings a portion of the reflected light beam from a light source on to a photocell. The photocell output is amplified and supplies the control field of a rotating regulator. A portion of the regulator output is fed back into the second galvanometer coil and tends to deflect the mirror in the opposite direction, so that a state of equilibrium exists when the two coil currents are equal. Hunting is avoided by inductive feedback between the galvanometer coils and the amplifier circuit. The indicated total current is given by the regulator output voltage which follows the totalized shunt voltage from zero to the rated current of the shunts.

For automatic regulation, the totalized plating current can be adjusted as a function of the speed of the tinning line. A block diagram of the current-speed regulator is given in Fig. 3.

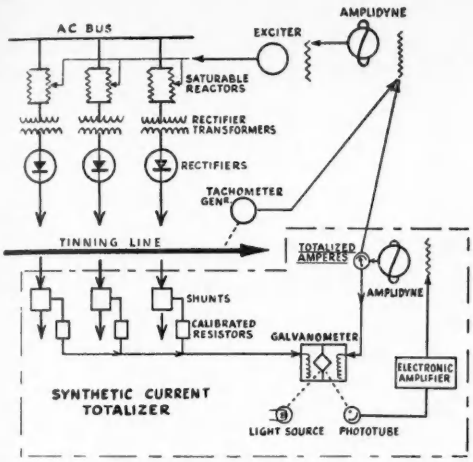

Fig. 3. **Synthetic current totalizer and associated equipment used for current-speed regulation for tin-plating line.**

The output of the above rotating regulator is fed to the field of a second rotating regulator which is supplied from a tacho-generator connected to one of the line drive motors. The output of the second regulator then controls the field of the exciter which supplies the voltage to the d.c. windings of saturable core reactors in the primaries of the rectifier transformers. Each reactor has an a.c. winding with a reactance and voltage drop depending on the magnetic saturation produced by the d.c. winding. Thus, the primary voltage of each rectifier transformer and the plating current from each rectifier are controlled easily and accurately. All the totalizer equipment is mounted on anti-vibration supports.

ROTATING REGULATOR AMPLIFIER

A new rotating regulator power pack has recently been developed which can be economically produced in great numbers. The package consists of a 1500-watt rotating regulator unit with a 150-watt direct-connected exciter, and an electronic amplifier and regulator mounted in a compact enclosure on one side. The power pack can be connected to a tacho-generator on a motor to provide speed regulation to ± 1 per cent. The tachometer generator voltage is compared with an adjustable reference voltage from a built-in voltage regulator tube, and the error voltage amplified in the electronic portion varies the field of the regulator portion, which in turn reduces or boosts the field of the motor or the generator supplying it, to hold constant speed. Another application is that of proportioning load among motors, in order to prevent overloads. This is achieved by comparing the line current of each motor with a reference by the electronic portion, which, in turn, controls the action of the rotating regulator which raises or lowers the motor speed until the motor is properly loaded. An anti-hunt device built into the unit ensures smooth motor operation.

REGULATING SYSTEMS

Using an electronic pre-amplifier and a rotating regulator final amplifier, the size of the machines regulated can be increased to about 3,000 kilowatts. The speed of response is slightly slower than that of the fully electronic regulator, but nevertheless is still very fast. The system has been successfully applied to steel mill drives and power rectifier regulation. The amplifiers and regulators are of rugged design, and fit into flush-mounted draw-out type cases. One of the most important features of all these combination regulators is that they have no dead band of operation, and control is effective immediately the tendency to vary has become a reality.

SWEDEN

The Swedish 380 kV Transmission System

By A. Rusck and B. G. Rathsman. (From *Asea Journal*, Vol. 22, No. 7, July, 1949, pp. 107-117, 11 illustrations.)

It has been estimated that the water power resources in Sweden which can be economically utilised for hydro-electric schemes have a potential annual output of about 50×10^9 kWh. Of these sources, 15 per cent are situated in the southern parts of the country, and 85 per cent in the less densely populated north.

Since 1936, when the first 220-kV power transmission line was put into service, the power transmission system running from north to south has been gradually expanded so that it now comprises five parallel lines, with a sixth line also approaching completion.

In 1946 it was decided to harness Harsprånget, Sweden's biggest waterfall, situated 22 miles north of the Arctic Circle, and 600 miles from the consumer centres in the south. A 380-kV line will be used for power transmission, with a maximum service voltage of 400 kV. Despite the promising results achieved at the experimental station at Trollhättan, the development of d.c. systems was not sufficiently advanced for their use in the Harsprånget project, and a.c. transmission has, therefore, been adopted.

The plant in its first stage will include a power station with step-up transformers at Harsprånget, connected by a line, 593 miles long, to a transformer station at Hallsberg for stepping down the voltage to 220 kV, and a 380/220 kV transformer station at Midskog, half-way between the two terminals, where the 380-kV line will link up with the 220-kV network. Further power sources in the Midskog district with an aggregate output of $1{\cdot}2 \times 10^9$ kVA will also be connected to the 220-kV network (see Fig. 1).

The majority of Swedish power line systems is operated with neutral earthing through a Petersen coil. This arrangement has also been applied to the 220-kV system and proved adequate until the transmission lines reached lengths of 1900 miles, when the arc extinction became uncertain. In the 380-kV system, design and economy considerations have made it preferable to choose a solidly earthed neutral, instead of the Petersen coil.

According to Swedish Standard Specifications, a 380-kV system calls for a station insulation level of class 1775, i.e., an insulation capable of withstanding 1775 kV on 1/50 full wave. However, for a solidly earthed system it should be permissible to reduce the insulation level by about 20 per cent. However, certain complications arose in the projected 380-kV system, as, owing to the extremely long transmission lines, the system will be subjected to exceptionally high voltages when one line end is disconnected. In the event of an earth fault, in the most adverse case, the voltage to

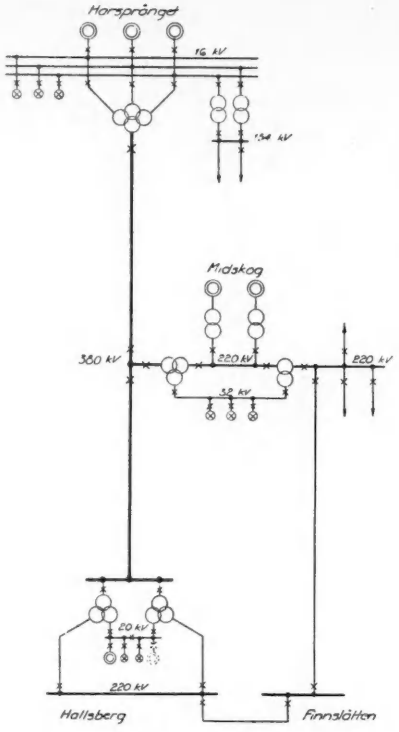

Fig. 1. **Line diagram showing first stage of the 380-kV system.**

earth at the open end of the line may be more than 200 per cent of the normal voltage to neutral, while at the 380-kV busbars in the power station it may rise to about 180 per cent.

Adequate surge diverters with a reseal voltage leaving a safe margin for normally occurring over-voltages were therefore required, and it was also necessary to raise the requisite minimum insulation level to ensure adequate protection. Calculations showed that the lowest insulation level should be about 1550 kV for apparatus in the immediate vicinity of the surge diverters, and 1750 kV for plant equipment situated within reasonable distance of the surge diverters. The difference in cost for transformers of classes 1775 and 1550 was only 5-9 per cent, and was, therefore, considered too slight to justify any attempted saving at the expense of insulation quality. The insulation class 1775 was, therefore, specified for transformers, circuit breakers, and other switchgear apparatus, which shall be tested to withstand the following values:—

Impulse test 1/50 full wave	1775 kV
50 cps a.c., dry test	976 kV
50 cps a.c., wet test	781 kV

Line insulation is required to provide adequate safety against flash-overs due to lightning or switching surges, and the lowest line insulator elements must not be subjected to excessive voltage stresses. Table I specifies the number of elements attached to the suspension strings for the various types of insulators, the flash-over clearances and the approximate impulse strength. The most commonly used type of suspension string is type A with 20 elements, given in Table I, with an impulse strength of 1580 kV, a 50 cps withstand voltage of 940 kV when dry and 760 kV when wet. This should give

TABLE I. INSULATOR TYPES USED IN STRINGS FITTED TO SUSPENSION TOWERS, AND CORRESPONDING FLASH-OVER CLEARANCES AND IMPULSE STRENGTH.

Type	Spacing mm	Number	Flashover clearance* mm	Impulse strength** kV
A	170	20	2920	1580
B	158	22	3010	1620
C	146	23	2880	1560
D	146	23	2880	1560

*Across string. **At positive impulse 1/50 when wet.

adequate protection, as the over-voltages due to switching which are likely to arise with the type of circuit breakers selected should not exceed a value 2·5 to 3 times the system voltage. A grading ring fitted to the suspension insulators reduces the voltage across the bottom elements to a safe value.

POWER STATION AT HARSPRÅNGET

The power plant on the river Stora Lule Älv is a 1430 m (4700 ft) long stone-filled dam crossing the river. The generator house, blasted into the living rock, has its floor 75 m (250 ft) below ground level. After passing the turbines, the water is discharged through a $1\frac{3}{4}$-mile long tunnel, with a cross-sectional area of 2050 sq ft. The power plant will comprise three turbine sets, each rated at 107 m³/sec (3780 cu ft/sec). The total head will be 107 m (350 ft) and the aggregate power output 290 MW. Space for the future installation of a fourth set has been prepared. The generators are rated at 105 MVA, 16-kV, power factor = 0·9, and will run at a speed of 167 rpm. Because of the long-distance transmission, the machines are designed with low reactances: subtransient reactance of 15, and transient reactance of 22 per cent. Auxiliary power requirements are supplied by 1200-kVA 50-cps station generators mounted directly on the generator shafts.

Bare conductors carry the generated power to the step-up transformers also installed underground. The 16/390 kV transformer plant is of a special design which has been found to present economic advantages. It comprises four main single-phase transformers, each rated at 115 MVA, $16 \Big/ \frac{370}{\sqrt{3}}$ kV, and four single-phase regulating transformers of 9·3 MVA, $16 \Big/ \pm \frac{30}{\sqrt{3}}$ kV, connected to the neutral point of the 380-kV side. One of these transformer sets acts as a stand-by, and the other three form a unit common to the three generators. To obviate the heavy currents and short-circuit kVA which would arise if the generators were directly connected on the 16-kVA side, the main transformers are constructed with five core limbs and three separate 16-kV windings, one on each of the three central limbs, and each winding connected to the same phase on the three generators.

Two 60-MVA, 16/154 kV transformers supply power to a local 154-kV system. The location for one of these transformers will at first be used for a 135-MVA, 16/240 kV transformer, which during a transition period will be used to operate the 380-kV system at 220 kV. The equipment will also include three 40-MVA reactors. Three double-pole 16-kV circuit breakers will be provided for each single-phase unit to enable the 380-kV transformers to be switched in and out of circuit. The operating system will be so arranged that any three breakers connected to the same busbar will be switched off simultaneously, but will also be capable of being operated individually when switching over transformer phases. The remaining step-up transformers, generators and reactors will be provided with normal three-phase circuit breakers.

Cables running through a vertical shaft carry the power up to ground level, and from there by overhead cable to the switch-yard. Six single-pole circuit breakers are provided for handling the 380-kV power, one three-pole group being intended for normal service and the remaining poles for connecting the stand-by transformer and as a reserve for the service breakers.

TRANSMISSION LINE

The power cables are suspended from steel towers with a clearance of 12 m (39 ft) between phases, and a cross beam 23 m (75 ft) above ground level, the standard span being 330 m (1080 ft).

In areas where the line will be exposed to exceptionally heavy icing, the span will be reduced to allow the cables to carry a total load of 4 kg/m instead of the usual 3·3 kg/m normally allowed. To keep down the weight, the towers will be made of high-grade steel with a tensile strength of 52 kg/mm² (33 tons/sq in), the

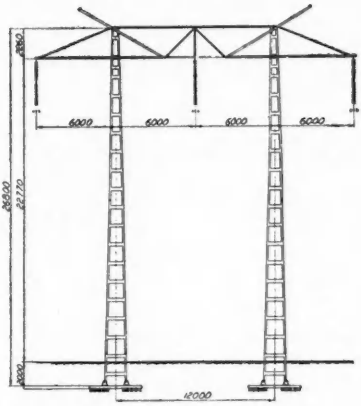

Fig. 2. **Standard line tower supporting double conductors for 380-kV system. Dimensions in mm.**

masts and cross-beams being built up of angle sections joined by welded bracing pieces which are corrugated for added stiffness (see Fig. 2).

The towers are raised on a foundation consisting of 8 to 12 sleepers joined by heavy beams, to which the two mast bases reaching up to ground level and carrying the mid-sections and superstructure are fixed. All steel parts are hot galvanized; the lower sections are also dressed with zinc sheet for protection against corrosion. On the cross-beams are mounted two arms supporting the steel earth wire of 70 mm² (0·109 sq in.) cross-section. The standard tower weighs 7·1 tons, which corresponds to approximately 22·5 tons of steel per km of line (36·2 tons per mile).

Double conductors suspended side by side, with a clearance of 45 cm, are used. These two 592 mm² (0·918 sq in.) steel-aluminium cables per phase, with a diameter of 31·7 mm correspond to two 330 mm² copper conductors, and give a line reactance reduced by 26 per cent as compared with a single conductor of large diameter. The double conductors give considerable improvement in line stability, raise the critical corona voltage, and are less costly than the tubular or expanded type single cable which includes non-conductive materials. Multiple conductors with 3 or 4 cables per phase would reduce the reactance and corona losses still further, but these gains would not outweigh the cost and added complication of design. The conductors chosen have an ohmic line resistance of 0·0275 ohm and a reactance of 0·33 ohm per phase and km, and a line capacitance of 0·011 microfarad per km, corresponding to a reactive power of 500 kVAr per km at 380 kV.

The cables are tensioned to 6·0 kg/mm² at 0° C, hanging under their own free weight, and the sag of a normal span is 10·2 m. To counteract the electromagnetic pull which predominates at heavy currents, it is necessary to fit distance pieces at intervals of not more than 350 m (1150 ft) to maintain the clearance between the conductors. However, owing to the corona voltage it is also essential that the conductors shall not approach one another closer than 20 cm, apart from occasional sway due to high winds. Tests still in progress indicate that these distance pieces must, therefore, be inserted every 125-150 m (400-500 ft).

Single string insulators of 20 elements, with a total length of 4·2 m will be used for supporting a working load of up to 4 tons, this being adequate for 95 per cent of the towers (see Fig. 3). The remaining towers will

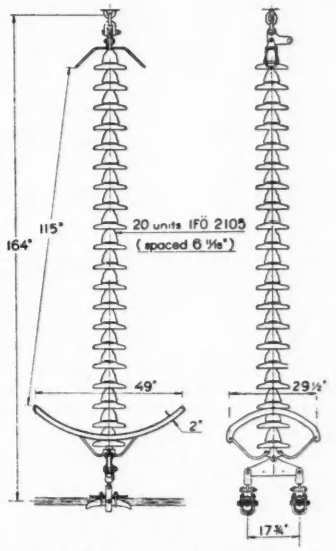

Fig. 3. **380-kV insulator string with grading ring.**

be fitted with duplicate strings, while the anchor towers will have triple or quadruple strings. The insulator strings are fitted with arcing horns at the upper end and a grading ring at the cable end to equalize the voltage on the two bottom insulator elements. Standard cable holders, fixed to a yoke suspended from the insulator string, carry the double conductor. The cables are whipped at the points of support for protection against damage due to fretting, and vibration dampers, 12 per tower, are fitted on either side of the holder.

TRANSFORMER STATIONS AT HALLSBERG AND MIDSKOG

At Hallsberg, the terminus of the 380-kV line, the power is stepped down to 220 kV and fed into the distribution network. The two transformer sets used comprise three single-phase units each, rated at $100/100/67$ MVA, $\frac{385}{\sqrt{3}} / \frac{256}{\sqrt{3}} / 21{\cdot}5$ kV, and a three-phase regulating transformer for 39 MVA, $20 / \frac{50}{\sqrt{3}}$ kV.

No stand-by transformers have been installed, as each of these sets is capable of handling the greater part of the power. The transformers have twin-limbed cores, the tertiary winding being connected to two loading reactors of 60 MVA each and a 75 MVA synchronous condenser, designed for hydrogen cooling. The tertiary winding also supplies the excitation current for the regulating transformers.

The outdoor 380-kV switchgear installation will have room for five lines, a double busbar system, and auxiliary busbars for by-passing any one of the line breakers. At first only two transformer circuit breakers will be installed, and arranged so that the breaker may be common to both transformers, if required.

At Midskog, the transformer station serves to link up the midpoint of the 380-kV line with the 220-kV system. The previously built power station has a total output of 95 MW, stepped up to 220 kV. The switchgear installation is being extended to adapt it to the new linkage. The connection between the 380 and 220 kV systems will be provided by four single-phase transformers, rated at 110/110/75 MVA, $\frac{400}{\sqrt{3}}\Big/\frac{258}{\sqrt{3}}\Big/ 36{\cdot}5$ kV and four single-phase regulating transformers for 15 MVA, 32 $\Big/\pm\frac{55}{\sqrt{3}}$ kV, the fourth set acting as a reserve.

As the 380-kV line Midskog-Hallsberg will be connected in parallel with the existing 220-kV lines, and the ratio R/X for the 380-kV line is only 0·08 as compared with 0·18 for the 220-kV lines, it is desirable to increase the proportion of the load transmitted on the 380-kV side in order to reduce losses. A phase-shifting transformer will, therefore, be installed on the 220-kV side at Midskog, giving a voltage displaced through 90° and amounting to about 25 per cent of the main voltage. This transformer is composed of three single-phase units, having a series winding on the 220-kV side and a 30-kV excitation winding which is energized from the tertiary winding of the 380/220 kV set via 30-kV busbars.

CIRCUIT BREAKERS AND RELAY PROTECTION

In its initial stage, the 380-kV system will be equipped with seven air-blast circuit breakers rated at 1000 A, having a rupturing capacity of 8000 MVA at 350 kV. The breakers will have non-linear resistors in order to reduce the voltage impulses due to switching. The breaker design enables high-speed reclosing to be carried out, single-phase or three-phase, in about 0·10 sec, at an operating pressure of 15 atm. Circuit breakers for the 220-kV system will be of basically similar design, having a rupturing capacity of 5000 MVA, and air-blast breakers will also be used for the lower voltages. Interlocking of certain breakers and isolators has been introduced in order to obviate faulty operation.

Relay protection for the lines is furnished by distance protection with supplementary carrier protection, so that it is possible in the event of a single-phase fault to effect disconnection and high-speed reclosing of the affected phase only. A new high-speed breaker design is now nearing completion. The protection is energized by a capacitor voltage transformer and separate current transformers, connected to the conductor to be protected.

Separately mounted current transformers installed at the main transformers are a costly item, and have been replaced by current transformers of the bushing type. Selective disconnection in the event of flash-over is facilitated by arcing rings, earthed through simple current transformers with instantaneous current protection. The transformers are equipped with gas relays, differential protection, earth fault protection, and thermal over-current protection. The protection is designed so as to obviate the need for switching over in the secondary circuits of the instrument transformers when changing the line connections, etc. In some cases it may be necessary to redirect the tripping impulse to the circuit breakers.

OVER-VOLTAGE PROTECTION AND VOLTAGE CONTROL

The two earth wires protecting the conductors extend the full length of the line and present a shielding angle of 24 deg. at the suspension towers and 26·5 deg. at the mid-span. On the north line section the resistance to earth is reduced to a maximum of 30 ohms, while on the south section, where the frequency of thunderstorms is somewhat higher, the value is 25 ohms. Exceptionally robust surge diverters will be installed at Harspranget, and the switchgear equipment will be provided with a special earth wire protection extended to cover the two adjacent spans of the 380-kV line. Similar protection will also be provided for the 130-kV transformers, busbars, etc.

Each line section generates 250 MVAr at 380 kV. Various means are provided for selecting the voltage appropriate to various service conditions, namely the regulating transformers at the three stations, the eight reactors totalling 420 MVAr, the 75 MVA synchronous condenser at Hallsberg and the linkage with the 220-kV system at Midskog.

Initially, the north line section will transmit power only from Harspranget, about 300 MW, and the stability margin will be ample. According to model tests, the section Midskog-Hallsberg should be capable of transmitting about 400 MW without endangering the stability. The ohmic losses in the north line section Harspranget-Midskog at 380 kV and 300 MW input from Harspranget will amount to 7·6 MW. The corresponding losses in the south section will be 13·6 MW when carrying 400 MW. In addition, the corona losses will amount to about 2 MW in each line section, and thus bring the total line losses when transmitting maximum power to about 25 MW during the first years.

TIME SCHEDULE, COSTS, AND FUTURE EXTENSION OF THE 380-kV SYSTEM

The first generator at Harspranget is scheduled to come into operation in 1951, and the line Harspranget-Hallsberg should by then also be completed. However, owing to delays in delivery of equipment, the line will first be operated at 220 kV, and should be ready for putting the 380-kV system into operation towards the beginning of 1952.

Towards the end of 1952 a new power station at Storfinnforsen, supplying some 100 MW, will come into operation. This power and the power from a further station at Kilforsen will be fed into the 380-kV line at a point about 35 miles north of Midskog. Further extensions of the transmission system will gradually be carried out, and it is now estimated that six 380-kV lines will be required to carry all the hydro-electric power available.

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Impeller Design for Centrifugal Pumps and Compressors

By K. PANTELL. (From *Konstruktion*, Vol. 1, No. 3, 1949, pp. 77-82, 6 illustrations.)

THE design of impeller blades for centrifugal flow machines can be based on a wide variety of methods. Most reference books give several methods, without dwelling on their respective merits. This is because one type of calculation may in certain cases produce figures in closer agreement with experimental results for a given variable, for instance, the efficiency of the machine. The fact is that the behaviour of the turbine, which converts the energy of the working medium into power, is much less difficult to determine than that of rotary machines performing work on a medium.

In the turbine, the flow through the rotor is accelerated, and any eddies being formed are immediately carried away. In the centrifugal compressor or pump, however, it frequently occurs that the eddies either remain at their place of origin or drift to other positions while altering their size and shape. The free stream cross-section thus varies both locally and with respect to time. This is why purely geometrical methods of calculation, which give useful results for turbines, frequently fail when applied to centrifugal machines used for compression or expansion work. In a centrifugal flow machine, the blading should be designed to provide constant deceleration, and hence a uniform velocity gradient in the impeller passages.

The problem is difficult enough, even if reduced to two dimensions. The usual procedure is to assume that the stream can be resolved into two independent components: (1) a meridian stream, doing no work, situated in an axial plane, and (2) a peripheral stream, symmetrical relatively to the axis of rotation, to which energy from the blades is transmitted. The theoretical pressure head H_{th} and the true head H can then be obtained from the assumed head $H_{th\infty}$ in the usual manner [1].

CALCULATION OF BLADE PROFILE

After having drawn similar profiles in the meridian plane, the first operation is to determine the "mean stream line" in that plane. This line divides the meridian cross-section into two parts of equal absorbing capacity. As the meridian flow can be regarded as a potential flow, it is possible to construct a flow net, based on the type of profile chosen. The easiest procedure is as follows: Let s' = path, and c_m' = velocity along streamline, in the meridian section; then the velocity potential φ is related to s' by the relation

$$d\varphi = c_m' \, ds'.$$

The lines φ = const. are normal to the streamlines and to the blade contours. We can thus draw these normal lines (equipotential lines) spaced at equal intervals $\Delta\varphi$ and draw, perpendicular to two of these, a streamline element Δs (instead of the differential ds), defined by

$$c_m' \, \Delta s' = \Delta\varphi = \text{const.} = k_\varphi \quad (1)$$

For large cross-sections, two more streamline elements are needed between the two lines φ = const. already used, in order to divide the cross-section into four (instead of two) portions of equal absorbing capacity.

The curved quadrilaterals obtained in this manner have a mean length $\Delta s'$ and a mean width Δb. Let r denote the distance to the axis of rotation from the centre of each of these quadrilaterals (see Fig. 1). By virtue of the assumptions made, the quantity of fluid ΔQ between two streamlines is constant, so that we can write

$$\Delta Q = \frac{Q}{i} = \frac{\text{discharge quantity per sec.}}{\text{No. of stream sections}} = k_q$$

and, therefore, since $c_m' = \Delta s'/\Delta t$,

$$\Delta Q = 2\pi r \, \Delta b \, c_m' \quad .. \quad .. \quad .. \quad (2)$$

or with eq. (1)

$$\Delta Q = 2\pi \, r \, \Delta b \, k_\varphi / \Delta s' = k_q$$

so that

$$r \, \Delta b / \Delta s' = k_q/(2\pi k_\varphi) = k \quad .. \quad (3)$$

and this is valid for each complete strip between two adjacent φ-lines.

Eq. (3) can now be used to check the correctness of the strip, and errors are corrected by shifting sideways the streamline elements in the strip. The corrected line elements are connected smoothly to the streamlines previously constructed, and further strips, independent of the first one tested, are also checked and corrected in the same manner. Any change in direction of a streamline requires a corresponding alteration of the equipotential lines, since the two sets of curves are orthogonal. Generally, three or four equipotential lines are sufficient to determine the stream paths fairly accurately. The value of k in eq. (3) is, of course, different for each strip between equipotential lines. With a little practice, the mean streamline of the flow can thus be rapidly determined [2]. The velocity c_m' is obtained from eqs. (1) and (3).:

$$c_m' = \Delta Q/(2\pi \, k \, \Delta s') = k_q/(2\pi \, k \, \Delta s') \quad .. \quad (4)$$

where k = constant for the equipotential strip, and $\Delta s'$ = distance between the two equipotential lines of the strip at the point considered.

The numerical value of c_m' on the mean streamline can be obtained for each strip investigated. Inter-

[1] See, for instance: PFLEIDERER: Kreiselpumpen, 2nd ed., Springer, Berlin; HÜTTE: Vol. 2, 27th ed., p. 709; and ECK: Ventilatoren, p. 29.

[2] Further details on the determination of flow patterns are given in "Wasserkraft u. Wasserwirtschaft," 1937, p. 26.

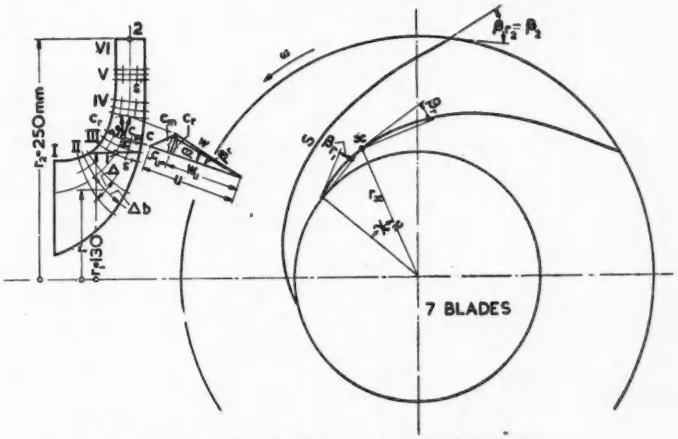


Fig. 1. **Centrifugal pump impeller** (Example 1).

mediate values are easily determined graphically by plotting the $c_{m'}$-vectors on the stream-lines s'.

Thus, the projection s' of the mean length s of the blade passage and the corresponding meridian velocity $c_{m'}$ are known. As the blades are not infinitely thin, the true meridian velocity c_m has a mean value somewhat greater than $c_{m'}$. However, this difference is generally extremely small, and will be neglected for the time being, as the correction can only be assessed after completing the construction of the blade.

The requirement of a constant deceleration in the impeller passages can be formulated as

$$dw/dt = \text{const.} = k_w \quad .. \quad .. \quad (5)$$

The following notation will now be used, in conjunction with Fig. 1:—Let u = peripheral velocity, c = absolute velocity (impeller), w = relative velocity, β = angle between w and $-u$, dt = time element, s = mean path of streamline, s' = projection of s in meridian plane, s'' = projection of s in horizontal plane. Subscripts 1 and 2 denote impeller inlet and outlet respectively, m denotes projection in meridian plane, u denotes projection in the peripheral direction, and r denotes projection in the radial direction.

Furthermore, let ϑ = angle between c_m and c_r, and hence between s' and r, χ = the angle from the beginning of the blade to the point considered, in the horizontal plane. We thus have

$$w = ds/dt$$

where s = mean length of passage (i.e., true length of the curved line in space shown by the two projections s' and s'' of Fig. 1). Eqs. (5) and (6) then give

$$\frac{dw}{dt} = \frac{ds}{dt}\frac{dw}{ds} = w\frac{dw}{dt} = k_w \quad .. \quad (7)$$

Furthermore, since $c_m = ds'/dt$,

$$c_m/w = ds'/ds \quad .. \quad .. \quad (8)$$

and $$c_m = w\,ds'/ds = k_w\,ds'/dw$$

or $$dw = k_w\,ds'/c_m \quad .. \quad .. \quad (9)$$

The relative velocities w_1 and w_2 at the blade inlet and outlet being already known from a preliminary calculation, we can integrate eq. (9), in the first place to obtain the value of k_w:

$$w_2 - w_1 = k_w \int_1^2 \frac{ds'}{c_m} = k_w s_{12}$$

or $$k_w = (w_2 - w_1)/S_{12} \quad .. \quad .. \quad (10a)$$

The value of the integral S_{12} can be found graphically as the area under the curve $1/c_m$ plotted as a function of s'. If desired, k_w can also be obtained as a function of r instead of s', since

$$c_r/c_m = dr/ds' = \cos\vartheta$$

so that with

$$\int_1^2 \frac{dr}{c_r} = R_{12}$$

$$k_w = (w_2 - w_1)/R_{12} \quad .. \quad .. \quad (10b)$$

Having found k_w, we can now calculate $w = w(s)$ or $w = w(r)$ for any given point x on s' by integrating eq. (9) up to the point x:

$$w = w_1 + k_w S_{1x} \quad .. \quad .. \quad (11a)$$

$$w = w_1 + k_w R_{1x} \quad .. \quad .. \quad (11b)$$

where $S_{1x} = \int_1^x \frac{ds'}{c_m}$ and $R_{1x} = \int_1^x \frac{dr}{c_r}$.

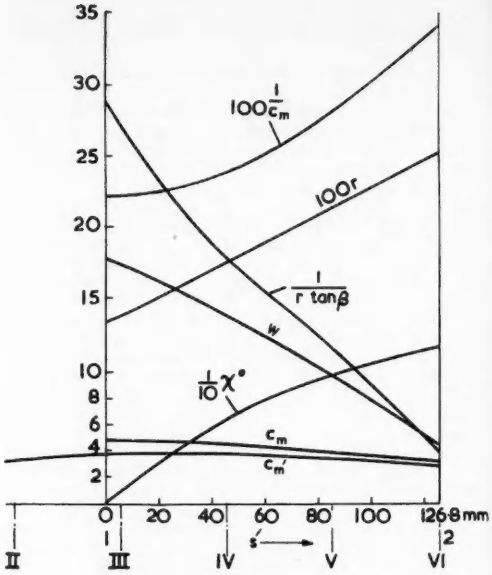


Fig. 2. **Curves and graphical integrations used in example 1.**

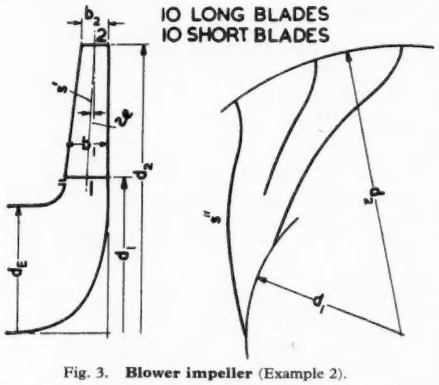


Fig. 3. **Blower impeller** (Example 2).

To determine the blade dimensions it is necessary to know the angle β:

$$\sin\beta = c_m/w \quad .. \quad .. \quad (12a)$$

or $$\sin\beta = c_r/(w\cos\vartheta) \quad .. \quad .. \quad (12b)$$

The component of w in the peripheral direction is

$$w_u = r\,d\chi/dt \quad .. \quad .. \quad (13)$$

hence $$c_m/w_u = ds'/(r\,d\chi) = \tan\beta \quad .. \quad (14)$$

or $$d\chi = ds'/(r\tan\beta) \quad .. \quad .. \quad (15)$$

Integration of this equation gives the angle χ for any point x on s' or r:

$$\chi = 57{\cdot}3 \int_1^x \frac{ds'}{r\tan\beta} \quad [\text{deg.}] \quad .. \quad (16a)$$

or $$\chi = 57{\cdot}3 \int_1^x \frac{dr}{r\tan\beta\cos\vartheta} \quad [\text{deg.}] \quad (16b)$$

We have thus found corresponding values of χ and r by means of which the contour s'' in the horizontal plane can be plotted. Two examples will now be given to illustrate the practical application of this method.

ILLUSTRATIVE EXAMPLES

Example 1: It is required to determine the blade shape of a centrifugal pump, for which the impeller contour in the meridian plane, and the inlet and outlet angles β_1 and β_2 have already been determined, so that $\beta_1 = 15°$, and $\beta_2 = 45°$.

The flow pattern is first plotted, as previously described. Referring to Fig. 1, if the running speed is $n = 1250$ rpm, and $r_1 = 0{\cdot}13$ metre, we have

$$u_1 = 2\pi r_1 n/60 = 17 \text{ m/sec.}$$

The moment of momentum is still equal to zero in front of the impeller passage, hence $c_{u1} = 0$, and the inlet triangle is right-angled, so that

$$\tan \beta_1 = c_{m1}/u_1$$

and $$c_{m1} = u_1 \tan \beta_1 = 17 \tan 15° = 4{\cdot}55 \text{ m/sec.}$$

The contraction coefficient k_ν at the inlet (point 1) is estimated first as $k_\nu = 0{\cdot}775$ (this will be checked later on). Therefore, we have for the flow pattern

$$c_{m1}' = c_{m1}\, k_{\nu 1} = 3{\cdot}53 \text{ m/sec.}$$

The plot of the flow pattern for the potential strips I to VI gives the values listed in Table I.

TABLE I

Strip between equipotential lines	k [m] (eq. (3))	s' [m] (from drawing)	$c_m'(s')$ [m/sec] (eq. (4))
I	—	—	2·81
II	0·1811	0·01775	3·26
III	0·1575	0·01850	3·61
IV	0·2115	0·01425	3·49
V	0·3300	0·01000	3·18
VI	—	—	2·81

The values of c_m' given in this table were first calculated with an arbitrary value for k_q and plotted against s'. The scale for c_m' was then corrected in such a way as to make the value of c_m' equal to 3·53 m/sec at point 1 of the mean streamline s'.

Further values required for the construction of the blade are given in Table II.

TABLE II

Point	1	—	—	—	—	2
s' [mm] ..	0	25	50	75	100	126·8
r [m] ..	0·130	0·1522	0·1767	0·2010	0·2232	0·2500
c_m' [m/sec]	3·53	3·62	3·50	3·295	3·065	2·81
k_ν ..	0·775	0·812	0·849	0·886	0·923	0·962
c_m [m/sec] ..	4·55	4·46	4·12	3·72	3·32	2·92
$1/c_m$ [sec/m] ..	0·2198	0·2242	0·2424	0·2688	0·3012	0·3422
S_{1r} [sec] ..	0	0·005510	0·011326	0·017706	0·024834	0·033474
w [m/sec] ..	17·56	15·35	13·01	10·45	7·59	4·14
$\sin\beta$ ..	0·2590	0·2905	0·3166	0·3560	0·4370	0·7060
β deg. ..	15·0	16·9	18·5	20·8	25·9	45·0
$1/(r \tan\beta)$ ..	28·70	21·85	16·94	13·07	9·22	4·00
χ rad. ..	0	0·6210	1·1050	1·4800	1·7575	1·9392
χ deg. ..	0	35·6	63·3	84·8	100·7	111·0

For simplicity, k_ν has been assumed to increase linearly from point 1 to point 2 along the mean line s'; the exact determination would require tedious checking, and the error involved is insignificant. The graphical evaluation of Table II is shown in Fig. 2. After calculating up to $1/c_m$ in Table II, the curve of $1/c_m$ over s' is integrated graphically, by measuring the area under the curve, to obtain S_{1r}. The value of k_w can then be calculated from eq. (10a), since the initial and end values of w are known:

$$k_w = (4{\cdot}14 - 17{\cdot}56)/0{\cdot}033474 = -401.$$

The remaining values of w are then obtained by means of eq. (11a). The integration of the expression for χ_{rad} is also obtained graphically by taking the area under the curve 1 ($r \tan\beta$). Corresponding values of r and χ_{deg} finally give the blade form s'' in the horizontal plane.

Example 2. The blading of a blower impeller, shown in Fig. 3, running at $n = 1450$ rpm, is to be

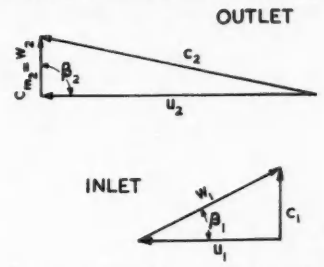


Fig. 4. **Velocity triangles for blower impeller of Fig. 3.**

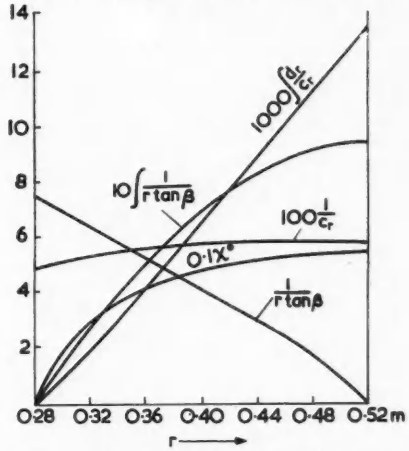


Fig. 5. **Curves and graphical integrations used in example 2.**

designed to take a volume $V = 10{,}000$ m³/hr at the inlet, the outlet angle being $\beta_2 = 90°$.

Owing to the small and practically constant angle ϑ, we can, in this case, dispense with the plotting of the flow pattern, and assume that, in the impeller flow passage, the mean line of the meridian contour is simply a straight line connecting the midpoint of b_1 and b_2. The widths b_1 and b_2 are measured parallel to the axis of rotation, although strictly speaking they are curved lines perpendicular to the streamlines. The angle ϑ can thus be determined from

$$\tan \vartheta = 0{\cdot}5\,(b_1 - b_2)/0{\cdot}5\,(d_1 - d_2) = 30/480 = 0{\cdot}0625,$$

or $\vartheta = 3{\cdot}6°$, and $\cos \vartheta = 0{\cdot}998$.

As $c_r/c_m = \cos \vartheta$, the difference between the two velocities can be neglected in the present case. Calculating with an average contraction factor of 0·97 to allow for the finite blade thickness, we obtain

$$c_r = c_m = V/(0{\cdot}97 \times 2\pi rb) = 2{\cdot}78/(0{\cdot}97 \times 2\pi rb)$$
$$= 0{\cdot}456/(rb) \quad .. \quad .. \quad (18)$$

The compressibility of the working medium, that is,

the variation of V, will also be neglected as usual. It can be taken into account at a later stage, as will be explained subsequently. Thus

$$c_{m1} \simeq c_{r1} = 0{\cdot}456/(0{\cdot}28 \times 0{\cdot}08) = 20{\cdot}35 \text{ [m/sec]}$$
$$c_{m2} \simeq c_{r2} = 0{\cdot}456/(0{\cdot}52 \times 0{\cdot}05) = 17{\cdot}5 \text{ [m/sec]}.$$

In this case the velocity diagrams at the impeller inlet and outlet both are right-angled triangles (see Fig. 4). Since the peripheral velocity is

$$u = \pi nD/60 = \pi\ 1450\ D/60 = 76\ D,$$

we have

$$u_1 = 76 \times 0{\cdot}56 = 42{\cdot}5 \text{ [m/sec]},$$
$$u_2 = 76 \times 1{\cdot}04 = 79{\cdot}0 \text{ [m/sec]},$$
$$w_1 = \sqrt{c_{m1}^2 + u_1^2} = 47{\cdot}2 \text{ [m/sec]}, \text{ and}$$
$$w_2 = c_{m2} = 17{\cdot}5 \text{ [m/sec]}.$$

Table III gives details of the calculation, and the corresponding curves are shown in Fig. 5. The second column gives the rotor widths b which decrease linearly along the rotor radius r.

TABLE III

r [m]	0·28	0·36	0·44	0·52
b [m]	0·08	0·07	0·06	0·05
c_r [m/sec]	20·35	18·15	17·30	17·50
$1/c_r$ [sec/m]	0·0492	0·0551	0·0579	0·0571
R [sec]	0	0·00419	0·00873	0·01336
w [m/sec]	47·2	37·9	27·8	17·5
$\sin\beta$	0·430	0·477	0·620	1·000
$\tan\beta$	0·477	0·543	0·791	∞
$1/(r\tan\beta)$ [m^{-1}]	7·46	5·12	2·88	0
χ [rad.]	0	0·504	0·824	0·940
χ [deg.]	0	28·8	47·1	53·8

The integral $R = \int \frac{dr}{c_r}$ is obtained graphically, and enables determination of the value of k_w in conjunction with eq. (10b):

$$k_w = (w_2 - w_1)/R_{12} = (17{\cdot}5 - 47{\cdot}2)/0{\cdot}01336 = -2225.$$

Furthermore, the value of w is determined from eq. (11b), and sin β and χ (deg.) are derived from eqs. (12b) and (16b), assuming $\cos\vartheta \simeq 1$. From corresponding values of χ (deg.) and r taken from Fig. 5, the blade contour in the horizontal plane is constructed as shown in Fig. 3. As 10 blades on the outer periphery would give rather large distances between the blades, 10 further blades similar in shape to the main blades, are added; these auxiliary blades, however, begin only at a radius $r = 350$ mm.

For rotors of high-pressure compressors, in which the *effect of compressibility* cannot be neglected, the treatment can be as follows:—Two blade contours are constructed, one for the inlet volume entering the blade, and the other for the outlet volume leaving the impeller. The outlet volume is determined by means of a temperature/entropy diagram. The actual blade form is then obtained by drawing a suitable transition from the first blade contour to the second.

DESIGN CRITERIA

Some criteria will now be given for the comparison of different blade designs. The decisive feature of any blade shape is the course of w as a function of s. Thus, if a blade contour is already built or laid out on the drawing board, it can be checked by first plotting the mean streamline s' of the flow pattern, and then determining the true length of s from s' and from the projection s'' in the horizontal plane. This is achieved, for instance, by drawing s'' as a straight line (see Fig. 6), plotting the distances e between s' and a radius to the corresponding points of s'', perpendicular to these, and connecting the end points of these perpendiculars. This curved connecting line has the length s which is being sought. The angle ϑ, and the angle β_r in the horizontal plane, are taken from the drawing; c_m is determined from the flow pattern. Then

$$\tan\beta = \tan\beta_r/\cos\vartheta$$

and from eq. (12a)

$$w = c_m/\sin\beta.$$

The more closely the curve $w = w(s)$ coincides with the previously constructed nearly straight line connecting its end points, the better is the blade design.

The blade based on a single circular arc is determined by r_1, r_2, β_1 and β_2, and rarely gives even a moderately favourable w-pattern.

Blades consisting of 2 circular arcs for the same number of given parameters can be drawn in a double infinity of ways, since both the enveloping angle χ and the ratio ρ_1/ρ_2 of the two radii of curvature can be arbitrarily chosen. In practice, there are certain limits to the possible values for the variables; they still include, however, designs of very different quality. In any case a kink in the w-line at the transition point from ρ_1 to ρ_2 remains unavoidable.

Frequently, the blade design in the horizontal plane is begun by using the angle β_1 instead of the correct angle β_{r1}, which is somewhat smaller. In practice, this error in reasoning often leads to favourable results, as it increases the width of the inlet (measured perpendicularly to the streamlines) which is otherwise too small; this produces a more favourable result, which is more important than using the correct angle β_{r1}.

The evolute contour, which is sometimes recommended for the inlet end of the blade, leads to a most inefficient w-rise with the usual impeller designs which have a width decreasing from the centre outwards. This defect is reduced to some extent by the erroneous use of β_1 instead of β_{r1} as already mentioned.

A method somewhat similar to that described above

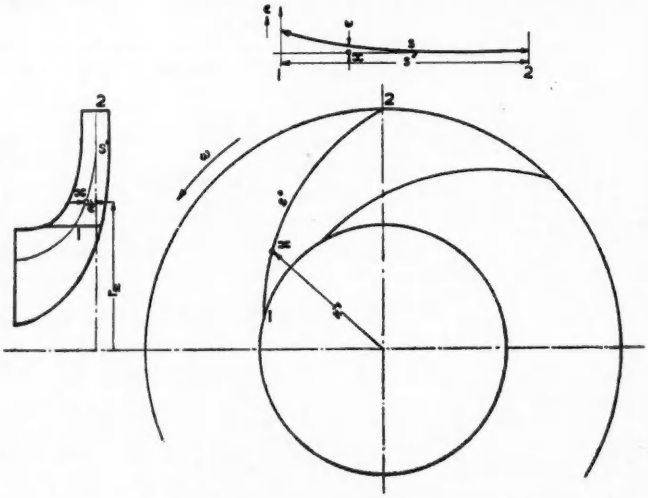


Fig. 6. **Determination of the true mean length s of the impeller flow passage from the projections s' and s''.**

has been developed by Pfleiderer for a point-by-point calculation of the blade form [3]. In Pfleiderer's method, however, the shape of the w-curve is an arbitrarily assumed function of r. In view of the complete lack of data on the physical characteristics of the flow, the plausible assumption is made that w decreases linearly along the radius r. This, however, leads to certain deviations from the constant value for deceleration. Nevertheless, this method makes it possible to avoid the occurrence of maximum and minimum values for the relative velocity between the two extremities of the blade, so that limits to the fluctuation of deceleration can be determined for rotors, provided that the w-drop is not too great.

The advantage of the method indicated in the present article is that it eliminates these uncertainties, since it is mainly based on physical and not on mathematical considerations. A check of the shape of the w-curve is, of course, unnecessary with this method.

[3] PFLEIDERER: Kreiselpumpen, 2nd ed., pp. 90 et seq., Springer, Berlin.

RUSSIA

Voltage Stabilization by means of Barium Titanate Capacitors

By G. I. SKANAVI and M. D. NEUMAN. (From *Elektrichestvo*, No. 7, 1949, pp. 43-46, 9 illustrations.)

PREVIOUS investigations by B. M. Vul and I. M. Goldman have shown that barium titanate has qualities characteristic of potassium sodium tartrate dielectrics. Capacitors with a barium titanate dielectric are non-linear, i.e., their capacitances are dependent upon the applied voltage and such capacitors can be used for a number of purposes. Frequency multipliers according to V. P. Vologdin and other investigators are based on the use of non-linear capacitors. The same applies to frequency modulators and frequency converters.

The authors investigated the possibility of using these capacitors for voltage stabilization. An a.c. voltage U applied to two capacitors in series, namely, a linear capacitor C_1 (mica) and a non-linear capacitor C_2 (barium titanate), is divided into two voltages U_1 and U_2 across both capacitors in inverse proportion to their capacitances (Fig. 1). The capacitance C_2 increases with increasing applied voltage U_2. An increase in the input voltage U increases U_2 at C_2, the capacitance of which grows. The relative increase of U_2 at C_2 is therefore, smaller by $UC_1/(C_1 + C_2)$ than the relative increase of U.

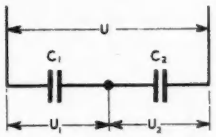


Fig. 1. **Basic diagram of voltage stabilization. A linear capacitor C_1 in series with a non-linear capacitor C_2.**

To solve the problem in question, it was essential to determine the material best suited for the non-linear capacitor C_2, which should be compatible with the highest dependency of the dielectric permittivity ϵ on the voltage and the technical requirements. Pure barium titanate has quite a high firing temperature. This temperature can be lowered by introducing additional substances into barium titanate, but these substances entail changes in $\epsilon = f(U)$. Fig. 2 shows ϵ as a function of the dielectric stress E in kV/cm for barium titanate with and without additions. An increase in additional substances lowers the initial value of ϵ and shifts the peak of the curves towards lower voltages. In this connection, the non-linearity is more pronounced at lower voltages in samples containing additions. The reason for this behaviour seems to be that the additional substances introduced render the crystalline grid "softer," the degree of adhesion of some of the grid ions being lowered, so that the effect of non-linearity and saturation is shifted in the direction of lower voltages. The experiments were carried out with capacitors containing additions of 1·5 per cent.

It was found that the circuit in Fig. 1 was not suitable for achieving practical advantages. It does not provide sufficient stabilization of U_2, even at no-load. At load, the capacitance C_2 influences the voltage distribution and introduces a further deterioration of the stabilization. The capacitance and loss angles of the capacitors used are shown in the curves of Fig. 3 as functions of U. Applying the equation

$$U = \frac{q}{C_1} + \frac{q}{C_2}$$

and considering the relation $C_2 = C_0 \quad k\,U$, obtained by experiment, the expression

$$U_2 = \sqrt{\frac{(2\,C_0 + C_1)^2}{4\,k^2} + \frac{C_1\,U}{k}} - \frac{2\,C_0 + C_1}{2\,k} \quad \ldots (1)$$

will be obtained, where

q represents the electric charge, and
k the factor of non-linearity.

Differentiating eq. (1) with respect to U, we obtain

$$\eta = \frac{dU_2}{dU} = \frac{C_1}{\sqrt{(2\,C_0 + C_1)^2 + 4\,C_1\,kU}} \quad \ldots (2)$$

An increase of k decreases η; in other words, the higher the factor of non-linearity, the better will be the stabilization. It is convenient to express the non-linearity of a capacitor by the ratio of the relative increase of the capacitance to the change of voltage:

$$k' = \frac{k}{C_0}$$

It was established experimentally that k' is constant within a wide range of voltages. It follows from eq. (2) that

$$k' = \frac{C_1^2 - \eta^2\,(2\,C_0 + C_1)^2}{4\,C_1\,U\,\eta^2\,C_0} \quad \ldots (3)$$

At $C_1 = C_0 = 10^4\ \mu\mu F$ and $k' = 0{\cdot}05$ Volts^{-1}, η becomes 0·1. The capacitors used in the experiments had $k' = 0{\cdot}0066$ Volts^{-1}, i.e., they were about ten times smaller. This is the reason why the circuit of Fig. 1 could not produce sufficient stabilization, even at no-load.

The voltages across both capacitors C_1 and C_2 are shown in the curves in Fig. 4 as functions of the input voltage U. A closer inspection of these curves reveals that it might be of more advantage to use the voltage

difference $U_2 - U_1 = \Delta U$ as a stabilized voltage, because this difference changes but little at a certain ratio of both capacitances within some voltage range. This led to the idea of making use in the following investigations of the circuit represented in Fig. 5.

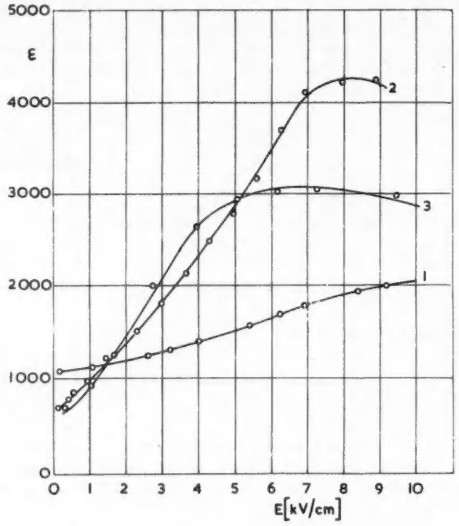


Fig. 2. **Dielectric permittivity of barium titanate as a function of the dielectric stress E.**
Curve 1—pure barium titanate, curves 2 and 3—with additions of 0·5 and 1·5 per cent respectively.

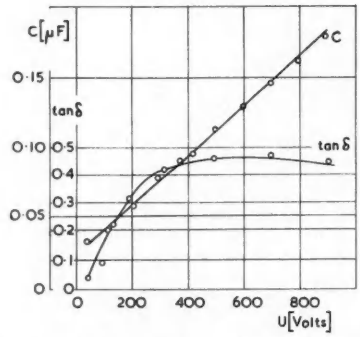


Fig. 3. **Capacitance and loss-angle of a barium titanate capacitor as functions of the voltage.**

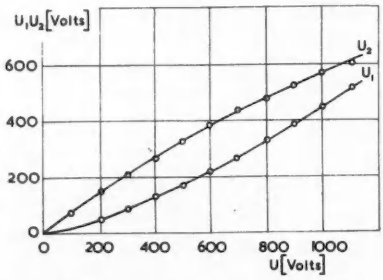


Fig. 4. **Voltages across the capacitors C_1 and C_2 as functions of the input voltage.**

The voltage in the diagonal of this bridge is equal to the difference between the voltages of the bridge arms ΔU.

The most suitable ratio C_2/C_1 was determined by a series of tests, the results of which are shown in Fig. 6.

The dielectric losses in barium titanate capacitors are considerably higher than those in capacitors of mica or paper (linear), and the voltage vectors U_1 and U_2 in Fig. 1 are, therefore, shifted in phase. The active resistance R_1 in the bridge, Fig. 5, is designed

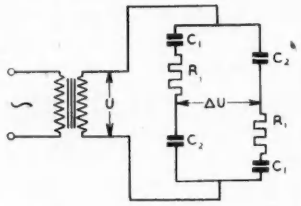


Fig. 5. **Basic diagram of a dielectric stabilizer.**
C_1—linear capacitor,
C_2—non-linear capacitor.

for partial compensation of this shift, because full compensation proved to be less favourable from the point of view of stabilization. The influence of R_1 in series with C_1 on the voltage in the diagonal of the bridge can be seen from the curves in Fig. 7.

It will be realised that in case of full compensation

$$U_2 - U_1 = \Delta U = \sqrt{\frac{(2\,C_0 + C_1)^2}{k^2} + \frac{4\,C_1\,U}{k}} - \frac{2\,C_0 + C_1}{k} - U \quad \ldots \quad \ldots \quad (4)$$

The curve 5 is calculated by this formula and this curve coincides sufficiently well with the curve experimentally obtained at $R_1 = 5$ comp. (curve 4), where the vectors U_1 and U_2 are only slightly shifted relative to each other.

Thus, it was established that by an appropriate choice of both the ratio C_2/C_1 and the resistance R_1

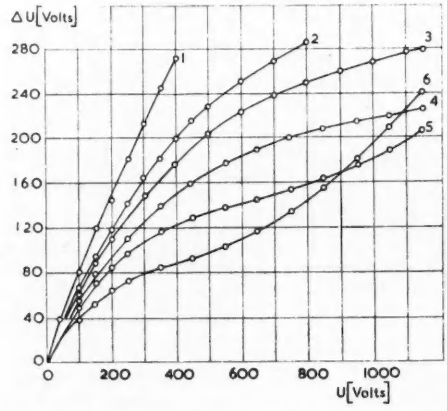


Fig. 6. **Voltage difference ΔU as a function of the input voltage U at different values of the linear capacitance C_1.**
C_1 in curve 1 — 0·45 μF; curve 2 — 0·23 μF;
curve 3 — 0·20 μF; curve 4 — 0·16 μF;
curve 5 — 0·13 μF; curve 6 — 0·10 μF.

in the circuit in Fig. 5, quite sufficient stabilization will be obtained for practical purposes.

The full calculation of the circuit in Fig. 5, with due consideration to the non-linearity, can be carried out by solving the following differential equation:

$$\dot{q}^3 R^3 - 3UR^3 \dot{q}^2 \sin \omega t + 3RU^2 \dot{q} \sin^2 \omega t + \frac{4RC_1}{k^3} \dot{q} + \frac{q}{k^3} - U^3 \sin^3 \omega t + \frac{C_1 U}{2k^3} \sin^2 \omega t = 0 \quad (5)$$

This equation can be solved by the method of successive approximations.

The value of the scheme in Fig. 5 is that the stabilization is not affected by the load, as can be realised from the curves in Fig. 8. The output obtained with the above-mentioned parameters is not conspicuous, but it can be increased without difficulty. If the non-linearity is not taken into account, the output in the diagonal of the bridge can be assessed by using the following approximative formula:—

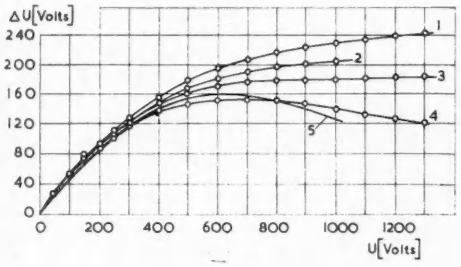


Fig. 7. **Influence of the load resistance R_1 on the relation of the voltage difference ΔU to the input voltage U.**
R_1 in curve 1 = 0; curve 2 = 1 comp.; curve 3 = 2 comp.; curve 4 = 5 comp.; curve 5 = calculated curve.

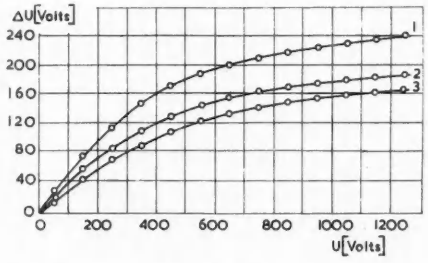


Fig. 8. **Voltage difference ΔU as a function of the input voltage U at $R_1 = 0$ and of different load resistances R.**
R in curve 1 = ∞; curve 2 = 30 comp.; curve 3 = 20 comp.

$$P = \frac{U^2 (z_2 - z_1)^2 R}{[2 z_1 z_2 + R (z_1 + z_2)]^2} \quad .. \quad (6)$$

where z_1 and z_2 represent the impedances of the arms, and R is the resistance of the load.

It follows that the output is a function of both the load R at constant input voltages and the impedances of the arms. In a purely capacitive bridge, the impedances are:— $z_1 = 1/(\omega C_1)$ and $z_2 = 1/(\omega C_2)$ and the maximum output of

$$P_{max} = \frac{U^2 \omega}{8} \frac{(C_1 - C_2)^2}{C_1 + C_2} \quad .. \quad .. \quad (7)$$

will be obtained at a load resistance of

$$R = \frac{2}{\omega (C_1 + C_2)}$$

Formula (7) shows that the output increases in the same ratio as C_1 and C_2 are being increased. The ratio C_2/C_1 must be so chosen as to obtain sufficient stabilization. The non-linear capacitance of the barium titanate capacitor introduces distortion in the shape of the voltage curve, just as does any other non-linear element of the circuit. The voltage curve can be analytically determined by solving the differential equation (5).

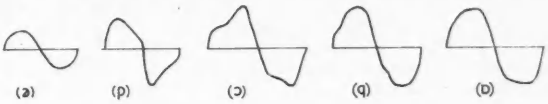


Fig. 9. **Oscillograms of output voltage of stabilizers under service conditions.**
Ferro-resonance stabilizers:—(a) U.S.S.R. Type EPA-15; (b) U.S.A. Type 162-A.; (c) German Type Siemens ESrg 1.
Dielectric stabilizers:—(d) R_1 = 2 comp.; (e) R_1 = 5 comp.

Fig. 9 shows oscillograms of the output voltage obtained with ferro-resonance stabilizers of different systems and with the dielectric stabilizer described above. It can be seen that the distortion of the sinusoidal voltage curve of the latter is not worse than that of the stabilizer first mentioned. At lower voltages, the dielectrically stabilized output voltage is considerably less distorted (curve 4, Fig. 7). The design and preparation of the first sample have shown that such a dielectric stabilizer of 50 watt output has approximately the same sizes as a ferro-resonance stabilizer, whereas its efficiency, which depends basically on the efficiency of the transformer, is higher. The losses are mainly due to the losses in the barium titanate dielectric. At tan $\delta = 0{\cdot}04$, the efficiency is nearly 100 per cent and the efficiency of the transformer is about 98 per cent.

Expressing $\xi = \dfrac{\delta U_{output}}{U_{output}} \Big/ \dfrac{\delta U_{input}}{U_{input}}$ as the coefficient of stabilization, the following table contains ξ for three ferro-resonance stabilizers and the dielectric stabilizer.

Type of Stabilizer	Coeff. of Stabilization
EPA-15 (U.S.S.R.)	0·000
162-A (U.S.A.)	0·068
Siemens ESrg 1 (Germany) ..	0·110
Dielectric Stabilizer (U.S.S.R.) ..	0·058

These data show that the U.S.S.R. ferro-resonance stabilizer produces the best stabilization, and that as far as the quality of stabilization is concerned, the dielectric stabilizer is just as good as the American and German stabilizers.

In comparison with the ferro-resonance stabilizers, the dielectric stabilizer has the advantage of being aperiodic, so that it is not sensitive to frequency fluctuations. Its manufacture is simple. The field of application of stabilizers is wide (stabilization of low-power systems, and of the input voltage of measuring instruments). The dielectric stabilizer can also be applied to higher frequencies, because the non-linearity is maintained in a wide frequency range.

CZECHOSLOVAKIA

A Diesel-Electro-Mechanical Drive for Traction Purposes

By V. KLIMA. (From *Elektrotechnický Obzor*, Vol. 38, No. 19, October, 1949, pp. 489-496, 13 illustrations.)

GENERAL

SHORTLY before the War, the Czechoslovak Railways put into service two high-speed motor coaches with a power transmission of a rather unconventional design, one axle of the motor bogie being driven mechanically through the generator, acting, as it were, as a magnetic clutch, and the other being driven electrically. Since then, this drive has been further developed and, at present, a three-unit train with two motor coaches incorporating this electro-mechanical drive is being built. In the following, this power transmission system is described and compared with the conventional diesel-electric drive.

The latter consists essentially of a diesel engine, a d.c. generator and a d.c. traction motor, as shown in Fig. 1. Although the equipment used in this arrangement is much heavier and more complicated than the equipment necessary for a purely mechanical transmission, which can also be used, the former system has been generally adopted for a number of well known reasons. In this connection, a brief survey of the essential points in dimensioning a conventional diesel-electric drive may be useful to enable a comparison to be made between this and the diesel-electro-mechanical drive subsequently described.

A diesel engine operates most efficiently when developing a constant torque at a constant speed, and it is, therefore, essential that it should operate under such conditions, despite the considerably varying conditions of speed and load which occur in railway service. The generator usually feeds a series traction motor, the speed of which is proportional to the square of the voltage applied. In the case of the conventional diesel-electric drive, it is, therefore, necessary to regulate the square of the voltage so that it is always proportional to the desired speed. Consequently, the current varies in such a manner that its square is inversely proportional to this speed. As regards the capacity of the generator which is necessary to transmit the power of the diesel engine, the following points must be considered. The generator must be able to provide a sufficiently high maximum voltage so that the maximum speed of the vehicle can also be reached at a low current; on the other hand, it must provide a certain maximum current at a lower voltage such as occurs when the speed of the vehicle is reduced. If both these conditions are to be met permanently, the generator as well as the motor must be able to withstand maximum voltage and maximum current in continuous operation without exceeding the temperature limits laid down by the national standards. The generator must, therefore, be dimensioned for maximum voltage as well as for maximum current, which means that its rated capacity is determined not only by the capacity of the diesel engine but also by the speed range of the vehicle within which it is desired to utilize the continuous capacity of the diesel engine.

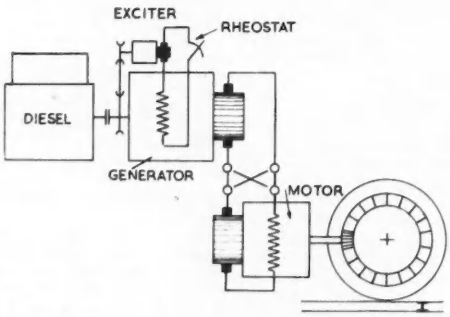


Fig. 1. **Schematic diagram of the conventional diesel-electric drive.**

If N_1, E_1, I_1 are output, voltage and current at a maximum continuous speed n_1, and N_2, E_2, I_2 the corresponding figures for a maximum continuous speed n_2, then

$$\frac{E_2^2}{E_1^2} = \frac{n_2}{n_1}, \quad \text{or} \quad E_2 = E_1 \sqrt{\frac{n_2}{n_1}}$$

The rated output of generator and motor must, therefore, be

$$N_{\text{rated}} = I_1 E_2 = I_1 E_1 \sqrt{\frac{n_2}{n_1}} = N_1 \sqrt{\frac{n_2}{n_1}}.$$

This means that if a series motor is used, the generator must be designed for a capacity equal to the product of the maximum continuous capacity of the diesel engine and the square root of the ratio of the maximum and minimum speeds to be obtained without shunting.

For example, if the required maximum speed without shunting is 100 km/h (62 mph) and the minimum continuous speed 50 km/h, the square root of the ratio of these two speeds is 1·41 and the rated capacity of the generator must be chosen 41 per cent higher than the capacity of the diesel engine. If the speed range to be covered without shunting is 35 km/h to 140 km/h, the rated capacity of the generator must be twice the capacity of the diesel engine.

The motor of a diesel-electric drive must be designed for the capacity of the generator and for the lowest traction speed, as conditions become more favourable at higher speeds when both current and magnetic field strength decrease.

THE DIESEL-ELECTRO-MECHANICAL DRIVE

Here, the diesel engine drives the stator of a d.c. generator, the armature of which is mechanically coupled to one of two driving axles, while the armature winding is electrically connected to the rotor winding of the traction motor, this motor driving the second axle (Fig. 2). Both field windings are fully excited. In this manner, the generator acts similarly to a magnetic

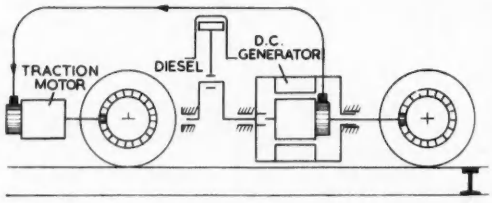


Fig. 2. **Schematic diagram of the diesel-electro-mechanical drive.**

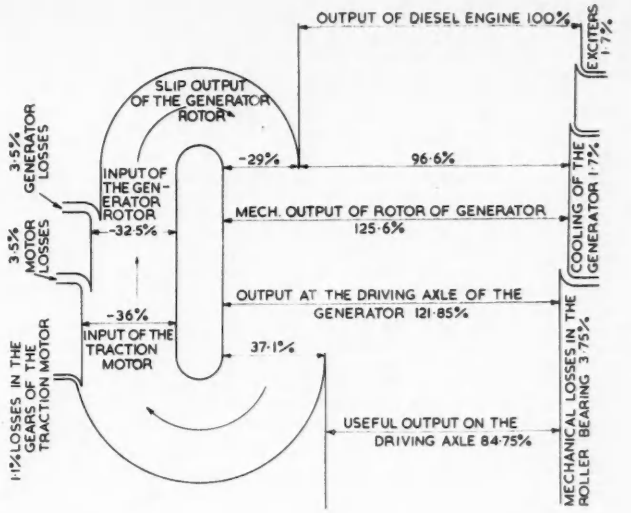

OUTPUT OF DIESEL ENGINE 100%
EXCITERS 1·7%
SLIP OUTPUT OF THE GENERATOR ROTOR
3·5% GENERATOR LOSSES
INPUT OF THE GEN-ERATOR ROTOR
-29%
96·6%
3·5% MOTOR LOSSES
-32·5%
MECH. OUTPUT OF ROTOR OF GENERATOR 125·6%
COOLING OF THE GENERATOR 1·7%
OUTPUT AT THE DRIVING AXLE OF THE GENERATOR 121·85%
-36%
INPUT OF THE TRACTION MOTOR
37·1%
1·1% LOSSES IN THE GEARS OF THE TRACTION MOTOR
USEFUL OUTPUT ON THE DRIVING AXLE 84·75%
MECHANICAL LOSSES IN THE ROLLER BEARING 3·75%

Fig. 4. **Energy flow diagram for the diesel-electro-mechanical drive at 130 per cent of the synchronous speed.**

clutch, with the difference that the slip energy is not being wasted, but is transmitted to, and utilised in, the traction motor. It is obvious that the electrical output obtained from the armature of the generator is the difference between the output of the diesel engine and the mechanical output transmitted through the generator to its associated driving axle.

$$N_{el} = N_d - N_{mech}.$$

As the torques of the diesel engine and the generator are equal,

$$N_{el} = M_d (n_d - n_r) = M_d n_d \frac{n_d - n_r}{n_d}, \text{ or}$$

$$N_{el} = N_d s, \text{ and } N_{mech} = N_d (1 - s),$$

s being the slip of the generator. This agrees with the electrical conditions, the electrical output being

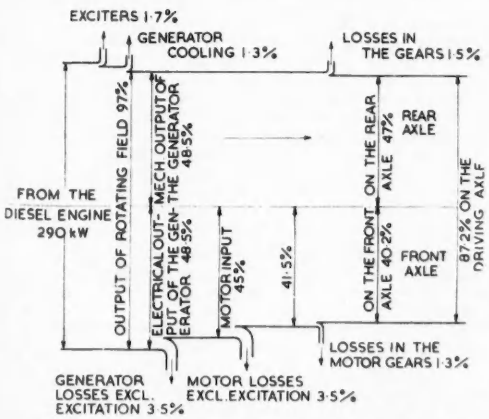

EXCITERS 1·7%
GENERATOR COOLING 1·3%
LOSSES IN THE GEARS 1·5%
OUTPUT OF ROTATING FIELD 97%
ELECTRICAL OUTPUT OF THE GENERATOR 48·5%
MECH. OUTPUT OF THE GEN-ERATOR 48·5%
ON THE REAR AXLE 47%
REAR AXLE
FROM THE DIESEL ENGINE 290 kW
MOTOR INPUT 45%
41·5%
ON THE FRONT AXLE 40·2%
FRONT AXLE
87·2% ON THE DRIVING AXLE
LOSSES IN THE MOTOR GEARS 1·3%
GENERATOR LOSSES EXCL. EXCITATION 3·5%
MOTOR LOSSES EXCL. EXCITATION 3·5%

Fig. 3. **Energy flow diagram for the diesel-electro-mechanical drive at 50 per cent of the synchronous speed.**

$$N_{el} = E_0 I s,$$

where E_0 is the voltage induced in the rotor when it is at a standstill, and I the rotor current.

Consequently, at a slip of $s = 1$, the whole output of the diesel engine is transformed into electrical energy $E_0 I$. At 50 per cent slip the speed of the generator armature is 50 per cent of that of the diesel engine and the mechanical power transmitted equals 50 per cent of that at the shaft of the diesel engine, the remaining 50 per cent being transformed into electrical energy and utilised in the traction motor. When the slip is $s = 0$, the entire output of the diesel engine is transmitted to the axle driven by the armature of the generator, and the slip output is zero. Obviously, to reach and maintain this state of synchronism, a current must be kept flowing in the armature; as, however, no voltage is induced in the rotor when there is no slip, the necessary current must be supplied from an outside source; in this case, this is the traction motor, which must, therefore, cease to operate as such and must become a generator driven by the axle of a vehicle similarly to a lighting dynamo. To achieve this, the excitation of the motor is reversed, and thus a current can be maintained through the rotor of the generator even at synchronous speed. Over-synchronous speeds can be obtained by still further increasing the reverse excitation of the motor. This results in a higher current flowing through both rotors, thereby producing an increased torque, which, in turn, leads to a higher speed, i.e., to a negative slip. Apparently, at over-synchronous speeds, the generator rotor transmits to the driving axle an output higher than that produced by the diesel engine. This is true insofar as the "surplus" energy is transmitted only mechanically—through both driving axles being coupled mechanically over the rails—from the generator armature to the rotor of the motor, where it is transformed into electrical energy and, due to the negative excitation, fed back as such into the generator. Figures 3 and 4 show the energy flow diagrams for operation of the drive at 50 per cent and 130 per cent of the synchronous speed, respectively. It is interesting that in the first case, 87·2 per cent of the mechanical output of the diesel

engine is transmitted to the driving wheels. In the second case, the generator armature transmits to the rail 125·6 per cent of the output of the diesel engine; of this, 37·1 per cent is recuperated from the rail in the traction motor, which now operates as a generator, and this amount minus the motor losses of 3·5 per cent is transmitted back to the generator as electrical energy. The total losses in this case amount to 8·1 per cent (Fig. 4).

The main advantage of this type of drive lies in the fact that the rated capacity of the generator need only be equal to the capacity of the diesel engine, while the traction motor proper can be relatively small, even if operation at speeds below and above the synchronous is desired. For instance, in the example described, this would be 50 per cent and 40 per cent respectively, of the capacity of the diesel engine. Both the generator and the motor are, therefore, much lighter in weight than those required for a conventional drive having similar characteristics. In addition, a higher efficiency is obtained, which, in the examples described, reaches a maximum of 88 per cent (see Fig. 5), compared with 81 per cent for a corresponding conventional drive.

LOADING CONTROL OF THE DIESEL-ELECTRO-MECHANICAL DRIVE

The loading control of this transmission system is fully automatic. The generator is excited by its own exciter; the series traction motor is provided with an additional excitation from an exciter of special design. This machine of small remanence, called Labilodyne, has three field windings: an indirect series excitation, proportional to the main current: an inverse excitation from the exciter of the main generator; and a quick-response shunt self-excitation. The purpose of this machine is to vary the excitation of the traction motor automatically between a given positive and a given negative limit, so as to keep the main current at a predetermined value.

By maintaining current and magnetic flux in the generator constant, the torque is also kept constant; as, in addition, the generator is excited by its own quick-response exciter, the speed of the diesel engine also remains practically constant, so that the two conditions required for the efficient operation of a diesel engine, namely, constant torque and constant speed, are ensured.

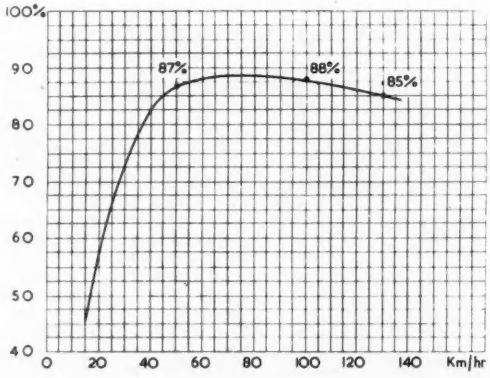


Fig. 5. **Efficiency of the diesel-electro-mechanical drive of a three-unit train with two diesel engines of 410 hp capacity each. Synchronous speed 100 km/h, max. service speed 130 km h.**

The transition from the sub-synchronous to the over-synchronous condition is automatic and does not require the attention of the driver. It is possible, therefore, to operate several units by multiple control, and the three-coach units now being built employ, in fact, multiple control for the two motor coaches.

The outstanding points in the design of the generator are as follows:—the stator runs in two roller bearings mounted in a silumin frame: current is fed to both stator and armature through slip-rings: the armature is of the drum type, but it has a radial type commutator, onto which the rotating brushes are pressed in an axial direction; the armature is hollow and the universal joint connecting it to the shaft is placed inside it; an electro-magnetically operated friction clutch between the diesel engine and the shaft of the universal joint, so designed that automatic clutching can take place only under conditions of absolute synchronism, makes it possible to run with a purely mechanical transmission between diesel engine and driving axle at an efficiency of 95 per cent; this clutch is actuated either automatically when appropriate, or by the driver. It was possible to design this clutch with metal friction discs so that its size and weight are very small, the latter being about 66 lb; the clutch, however, need not be used in service. Automatic operation of the clutch is supervised by a synchronisation control arrangement which is located inside the shaft; the exciters of the generator and motor, and a dynamo for battery charging, are mounted on the generator; the latter also serves as a starter for the diesel engine.

From the designer's point of view, an added advantage of this drive was that the generator could be designed for a large number of poles and for the maximum voltage occurring at standstill, as, in practice, the voltage corresponding to the slip under ordinary traction conditions is only about 50 per cent of the maximum. Due to the high voltage at standstill, the current in this condition is very low, so that—despite the fact that the whole generator was built around a relatively large tube, in which it was possible to place a large universal joint—a radial type commutator with a small number of carbon brushes could be used. As a result of the comparatively low relative speed between rotating stator and rotating armature, both the commutating voltage and the voltage between the segments are very small, and, consequently, satisfactory commutation and a small amount of wear of the carbon brushes are expected in service. The generator, designed for a transmission of 140 hp, weighs 1200 kg, (2640 lb) and the exciters 170 kg.

The traction motor has six poles and is designed with a cylindrical frame and for nose suspension. Due to a specially designed mounting of the driving wheels, it was possible to use roller bearings for suspending the motor. To reduce eddy current losses in the series and shunt field coils, stranded conductors were used. The gears are of the herringbone type and the pinion is supported by two bearings to reduce wear and noise. The box enclosing the gears is made of silumin. The weight of the motor, including suspension bearing, gears and gear cover, is 920 kg. The weight per hp of the motor is 6 kg (13 lb), and if the transmission is included, 7 kg, which is a very low figure.

An additional advantage of this drive is that each traction bogie forms a self-contained unit with short connecting cables. For repairs, such a bogie can easily be removed and, in fact, a complete spare bogie has been ordered, so that during repairs or overhauls the train can be kept in service.

The only disadvantage of this system is that the two driving axles are not equally utilised. This, however, is more than compensated for by the other advantages gained, this being even more so as the limit of adhesion of the main axle is far from being reached.

Installation and Maintenance of Pyrometers for the Heat Treatment Shop

By G. OESTEREICH. (From *Werkstatt und Betrieb*, Vol. 82, No. 10, October 1949, pp. 367-369, 3 illustrations.)

THE need for accurate measurement of temperatures in heat treatment furnaces has led to the general use of thermal pyrometers, usually in their simplest form as thermo-couples with directly connected voltmeters, but sometimes also in connection with automatic installations. These instruments require careful and regular maintenance and recalibration if measurements are to be reliable and reasonably accurate (to within ± 5 to 10° C). Faults always act in the direction of lower temperature indications and, thus, are additive. They can be prevented if the following simple rules are carefully observed.

The thermo-couple.

Fig. 1 shows the details of a thermo-electric pyrometer, the thermo-couple, the compensating connection and the voltmeter. Two wires of different metals are arranged within the protection tubes of the thermo-couple, their common ends being welded or soldered together at the hot junction, the opposite ends being brought out at the terminal head. The following wire materials are used :

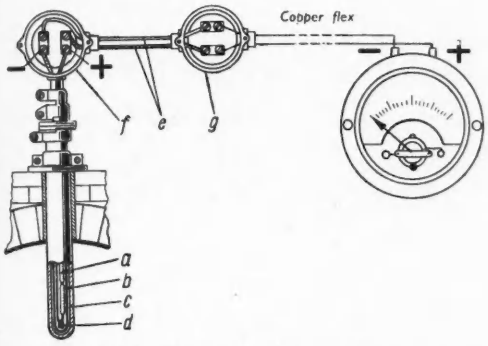


Fig. 1. **Thermo-electric pyrometer.**
a = Insulating tube ; *b* = gas-tight inner protection tube ; *c* = outer protection tube ; *d* = hot junction of couple ; *e* = compensating wires ; *f* = terminal head ; *g* = cold junction.

(1) For measurements up to 600° C, ⅛-in. constantan wires (55 Cu/45 Ni) joined to iron wires or iron protection tubes,
(2) up to 1100° C, ⅛-in. chromel wire (89 Ni, 9·8 Cr, 1·0 Fe, 0·2 Mn) joined to alumel wire (94 Ni, 2·0 Al, 1·0 Si, 0·5 Fe, 2·5 Mn),
(3) up to 1400° C, 0·02-in. diameter platinum wire joined to platinum-rhodium wire (90 Pt, 10 Rh).

The last mentioned couple is only used for high temperatures and where extreme accuracy is required.

The compensating wires, usually of 1·5 mm² (0·0025 sq in.) cross-section, are directly connected to the couple wires and consist of cheaper low-resistance alloys so chosen that up to 200° C their thermo-voltage is equal to that of the couple. They must, therefore, not be heated above 200° C and should be marked according to the type of thermo-couple to which they belong. They represent an extension of the couple wires and enable the cold junction to be placed at a suitable, uniformly cold, spot. For very accurate measurements, the cold junction is placed in a thermostat container kept at 50° C or in a receiver filled with melting ice. Copper wires of at least 1 mm² (0·0016 sq in.) cross-section then connect the cold junction with the voltmeter. For normal accuracy, the cold junction may be kept at room temperature at a point far enough from the furnace and not directly exposed to heat radiation or large temperature fluctuations, or it may be cooled in a constant stream of compressed air. Small fluctuations in room temperature can then be detected by a mercury thermometer and the thermo-couple reading corrected by simple calculation as follows : If the calibration temperature of the thermo-couple be 20° C and the actual room temperature at the cold junction be 25° C during reading, the difference between the two temperatures, i.e., 5° C, is to be added to the reading of an iron-constantan or chromel-alumel couple, but only half the difference is to be added to the reading of a platinum thermo-couple.

When compensating and connection wires are installed, care must be taken that the connections can be kept clean, and that the wires are protected from humidity and do not cross, or lead along, other a.c. cables, as induced stray currents might otherwise falsify readings. Thermo-couple wires for heat treatment furnaces are usually arranged inside an inner gas-tight protection tube of refractory ceramic material. An outer tube provides protection against mechanical damage ; nickel-chromium alloy steel tubes are used for temperatures above 800° C ; carbon steel tubes are satisfactory for use below this temperature. Damaged protection tubes lead to premature destruction of the wires through chemical attack by furnace gases or salt bath mixtures, and should be replaced as soon as possible. Forced-convection air furnaces with automatic temperature control requiring quick-acting response are provided with unprotected thermo-couples, since the air hardly attacks the thermo-metal wires.

Thermo-couples only give a few thousand hours of service. After a certain time, the thermo-voltage deviates from its original value, so that indication becomes unreliable. Generally speaking, the couples last longer, the lower the service temperature and the better the protection against chemical attack and mechanical vibrations. A regular check on accuracy is required after about every 50 to 100 hours of service. The service couple and a special, seldom used, gauge couple are then both immersed in a salt or metal bath, and the voltage of each is measured by means of one and the same voltmeter. Measured voltages are compared at two or three different temperatures, and if deviations exceed, say, 2 per cent, the checked couple should be taken out of service. For high-precision indication, the permitted deviation should be even smaller. If a salt or metal bath is not available, a heat treatment furnace can be used. The two couples are then inserted in neighbouring openings, their hot ends being as near together as possible and at least 4 inches from the furnace wall. In this case, as also generally during service, the openings should be sealed against the ingress of cold air, using, if possible, asbestos or clay packings, If the elements are inserted from the furnace ceiling. the air circulating inside the tubes would affect readings. Horizontal arrangements or insertion through the furnace floor are, therefore, preferred.

The voltmeter.

Moving-coil millivoltmeters with permanent magnets (galvanometers) are usually supplied for heat treatment shops. They are very sensitive and need great care and attention. Careful installation and exactly horizontal or vertical positioning are required. The instrument must not be exposed to vibrations and

should be protected against dust, and the service temperature should not appreciably deviate from 20° C. If necessary, the meter can be cooled by an air stream. Inaccurate or faulty instruments should not be tampered with, but should be repaired by experts. For a regular check on accuracy and possible faults, the following methods are recommended.

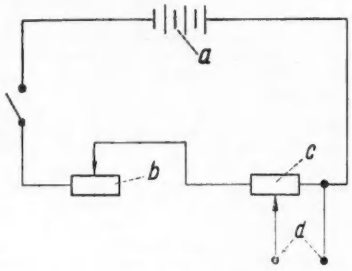


Fig. 2. **Circuit diagram of battery box for calibration.** *a* = torch battery of about 4 V; *b* = adjustable resistance, 50,000 Ohm max.; *c* = adjustable resistance, 5000 Ohm max.; *d* = terminals for measuring instrument.

A precision millivoltmeter with ranges from 0 to 18 mV and 0 to 60 mV and a current source with a voltage adjustable between 0 and 100 mV should be available in every hardening shop. The precision instrument can be bought on the market, but should be checked from time to time against a scientifically correct instrument. The terminals should be short-circuited before moving the instrument. The current source may be bought or fitted together from radio components and a torch battery as shown in Fig. 2. The temperature indicator should be re-calibrated after installation and before being put into service. The supplier usually calibrates this instrument for a temperature of 20° C at the cold junction and a total wire resistance of couple, compensating and connection wires of 1·5 to 3 Ohms. Re-calibration is always desirable. It is necessary when the temperature at the cold junction or the resistance deviates appreciably from these values.

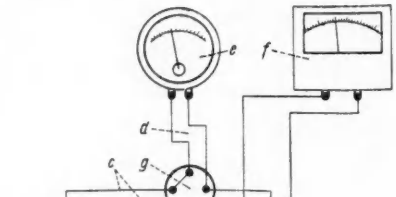


Fig. 3. **Circuit diagram for comparative re-calibration.** *a* = battery box (see Fig. 2); *b* = thermo-couple; *c* = compensating wires; *d* = connection; *e* = temperature indicator; *f* = control millivoltmeter; *g* = cold junction.

The regulating screw of the meter may have been moved during transport or installation. Simple re-adjustment at room temperature would then give no guarantee of correct indication at higher temperatures. This must be checked by the method shown in Fig. 3, which combines all the necessary local control and re-calibration requierments and guarantees adequate accuracy. The voltage of the current source is adjusted until a value corresponding to a given temperature of the couple appears on the precision voltmeter *f*. Values

TABLE 1. Comparative voltage values of the usual thermo-couples for a temperature of 20° C at the cold junction.

Temperature of hot junction (read on indicator *e*)	Corresponding thermo-voltage in mV (read on precision meter *f*) for thermo-couple of type.		
Temperature in C	Fe-const.	Ni-CrNi	Pt-PtRh
20	0·00	0·00	0·00
100	4·30	3·28	0·54
200	9·90	7·32	1·33
300	15·50	11·40	2·22
400	21·10	15·55	3·15
500	26·80	19·82	4·12
600	32·60	24·05	5·13
700	38·60	28·35	6·16
800		32·45	7·23
900		36·50	8·36
1000		40·50	9·50
1100		44·40	10·66
1200		48·20	11·85
1300			13·04
1400			14·25
1500			15·45

from Table I should be chosen, and corrected where necessary according to Table II. If the temperature indicated on the meter *e* deviates from this value, the meter *e* should be adjusted by means of the regulating screw. The service instrument *e* can thus be calibrated over the whole range of temperatures. After some time of service it will become slightly inaccurate and exact adjustment will then be possible over a restricted range of temperatures only. This exact range should just cover the temperatures needed in service.

TABLE II. Correction of voltage values of Table 1 for other temperatures at the cold junction.

Temperature of cold junction	Correction of thermo-voltage for thermo-couple of type:			Remarks
	Fe-const.	Ni-CrNi	Pr-PtRh	
20 C . .	nil	nil	nil	Use values of Table 1
50 C	1·55 mV	1·22 mV	0·19 mV	to be deducted from values of Table 1
0 C	1·05 mV	0·82 mV	0·11 mV	to be added to values of Table 1.

It may be necessary to check temperature indications during service. A second thermo-couple should then be introduced into the furnace and so placed that the hot junctions of both couples are as near together as possible. The checking couple is to be connected to the control millivoltmeter by means of compensating wires. If voltage and temperature indications do not correspond as shown in Table I (corrected if necessary), the service instrument should be taken out of service and investigated by the methods described.

PRODUCT DESIGN AND DEVELOPMENT

Some Aspects of Cabinet Design and Production

NOT so many years ago, design and production were regarded as two separate functions and exchange of ideas between the designer and the production engineer was not only discouraged but, in some firms, even disapproved. The designer's concern was to prepare drawings of a machine or any other product with only one objective in view, namely, that of attaining the highest possible degree of mechanical perfection, performance, and durability. The production engineer had no option but to carry out the designer's instructions and, under these circumstances, was often forced to resort to production processes which were economically unsound. The position is, of course, different now, the necessity for co-operation between designer and production engineer having been recognised as imperative to a greater or less extent; yet progress in this direction is still unsatisfactory in many industries.

To enlarge on this point, let us consider the production of steel cabinets, this being one of the most common examples to demonstrate the advantages that can be gained by bearing in mind production problems at an early stage in design. Generally, the design of a cabinet, whatever its intended use, presents no problems of mechanics or strength of materials. The factors on which our attention must be focussed here are production costs and appearance, and it will be our object to show that they are related to each other and to give reasons why only a consideration of both these factors together can lead to satisfactory results. Discussion of an abstract subject such as appearance is likely to lead to general disagreement, as, fortunately or otherwise, personal tastes will always differ. However, we do not wish to enlarge on this subject; suffice it to say that in our particular case, the shape of a cabinet leaves comparatively little scope for the designer. Therefore, in this case, we may well find it possible to agree that appearance does not enter into our considerations as a variable. Let us state then that the ideal cabinet is a low-cost unit of which we have already assumed that it is of pleasing appearance; also it must stand up well in service for a given period. The latter two requirements, by themselves, prevent no difficulties; it is only when they are required in a low-cost model that they may cause embarrassment. This is not merely true of mass-produced cabinets, but the same problem, although perhaps in a different form, will arise in production on a smaller scale. Whereas for very large-scale production it may be economical to install special-purpose machines designed for one particular operation, products for the small and medium sized manufacturer must be designed with due regard to existing equipment. Therefore, it is essential to make a study of the available manufacturing facilities before evolving a design.

Let us try to state the most important points which the designer has to keep in mind: he has to design around existing plant facilities, and specify low-cost materials consistent with rigidity and appearance of the cabinet; he has to consider the possibility of substitution of different materials in cases where price fluctuations suggest the desirability of changing over to another material; the same parts should be used for different models whenever possible in order to keep die investment down to a minimum; the use of prefabricated structures and standard parts should always be given due consideration, especially when limited quantities are required.

It should be interesting at this juncture to review production processes suitable for the manufacture of cabinets. Very high production usually justifies the use of stampings with attendant high die costs. However, when heavy presses are not available, or when the preparation of expensive dies is not considered economical, it will be found that press brake forming will be suitable for a wide variety of operations; in fact, it will be found that cabinets, even in comparatively large quantities, can be produced economically on this type of machinery, provided the designer is fully conversant with its possibilities and limitations.

The press brake was originally conceived to obviate the limitations and expense of wide-bed presses, and today offers a highly versatile and economical means of producing parts from sheet and plate which necessitate a long, narrow, forming bed.

Although the press brake is both suitable and largely used for performing long bending or forming operations (Fig. 2*), for which regular presses are not adapted, a wide variety of blanking, punching, notching, lockseaming, bending, wiring, and similar operations is readily accomplished. Generally, the work must be such that it can be produced on a long, narrow press bed with a relatively short ram stroke.

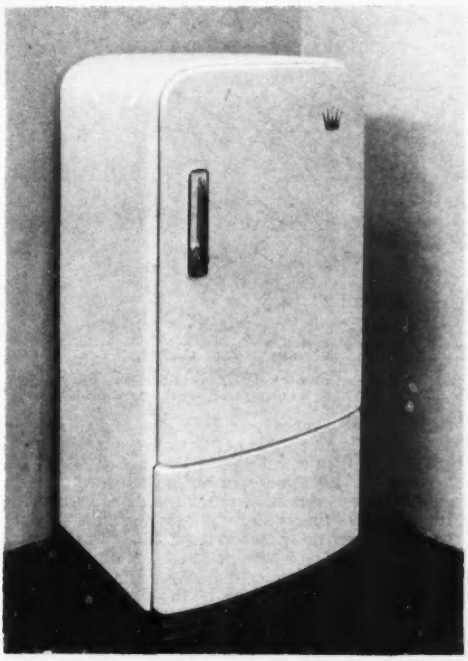


Fig. 1. **A modern refrigerator cabinet of pleasing appearance (Frigidaire Ltd.)**

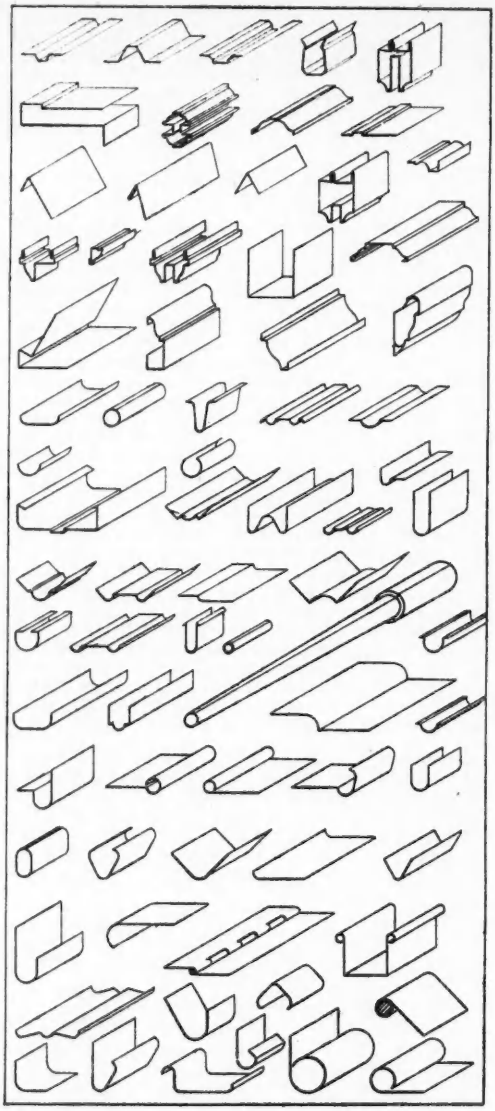


Fig. 2. **Representative group of cross-sections showing the general type and range of brake operations.**

Many types of press brakes are now available, some being more accurately termed " open-front " presses. These range in bed width up to 42 in. and in bed length from 6 to 30 ft, some special presses having even greater ranges. Press sizes range from small machines with a capacity around 20 to 25 tons for light bending of 14-gauge sheet up to 4 ft in length, to machines with a capacity around 900 tons for heavy work, but these will not be considered here.

The ram stroke required in the forming of parts must be relatively small, generally not more than 6 in. Standard brakes, however, are usually made with a 3 or 4-in. stroke. Simple adjustment provided on the ram as well as means for exactly recording such adjustments for duplication make possible the forming of many parts unattainable by any other method. This is especially true with work which must rise in front of, or behind the dies during forming. Again, work is not limited to the machine ram length, inasmuch as parts properly designed can be progressed-through in stages, when necessary, by virtue of the open construction at either end of a press brake.

A press brake differs considerably from either a press or a roll former where tool cost is concerned. Some of the factors which have to be considered before tooling the latter machines need not be considered when designing for the press brake. A few standard dies will produce a great variety of parts and are relatively inexpensive, Fig. 3*. By the use of " air bending," one set of acute-angle bending dies will form angles of any degree required, by merely controlling the distance to which the punch enters the die opening.

Standard brakes operate between about 5 and 50 strokes per minute. Handling of parts, however, determines the actual production capacity. With smaller parts, in some cases with automatic feed, production output may average 500 per hour. Multiple operations can be used on one machine to achieve rapid production, as many as ten separate functions being possible. Owing to the simplicity and low cost of the tooling on press brakes, trimming, punching, forming and similar operations are regularly performed in this manner in the production of cabinets, doors, tops, frames and panels for refrigerators and like equipment. This method also offers unusual freedom in the way of design improvements, since changes in tooling would entail relatively little cost.

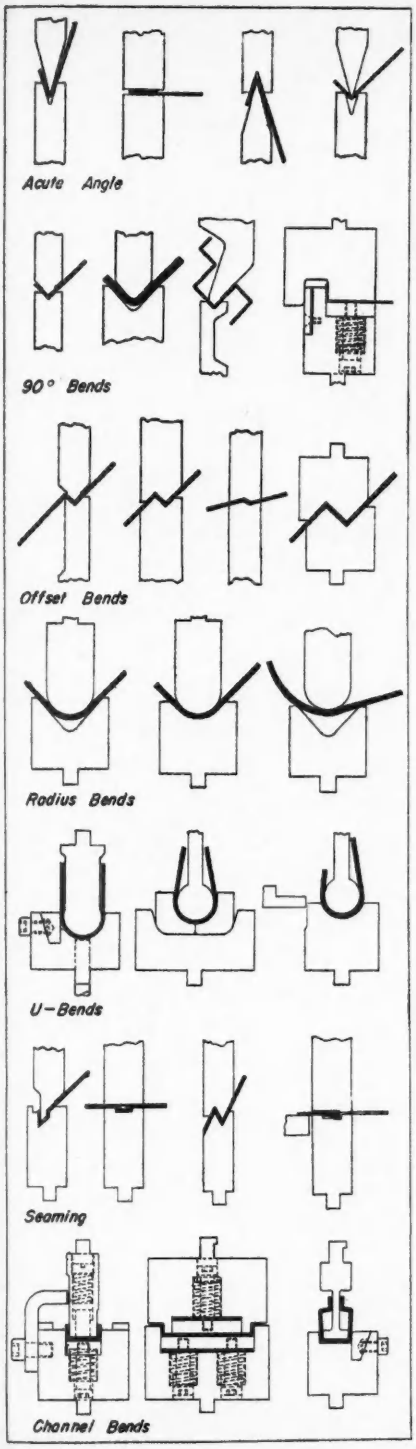
Insofar as design of parts is concerned, few general rules can be applied. Press brakes as well as dies for performing not only ordinary operations, but also an unlimited number of special-purpose operations, are extremely flexible. However, a number of normal limitations should be borne in mind in order to simplify production and achieve low cost of parts:—Work on operations to be performed should be such that they can be fairly symmetrical under the centreline of the ram, i.e., front to rear; material to be employed should be normally in sheet or plate form; and design should be such that the stroke available on press brakes will give proper clearance for easy and rapid handling.

Design for brake forming should, in most instances, avoid the necessity for making any but the simplest, shallow draws. Wherever possible, drawing should be obviated by using notched corners and welding, by adding welded ball corners, etc. Consideration should be given to the distances between notches, holes, etc., so as to permit of using simple tooling and allow single-stroke production. Since these conditions vary somewhat according to press size and design, doubtful designs should be discussed with the production department prior to completion.

Certain parts can be designed so as to lend themselves to progressive operations, especially where quantity will warrant expenditure on a special die arrangement. For example, where two operations are planned, these may be formed in double-deck dies in one handling. Here it is essential, however, that one operation be at the edge of the sheet so that it can be performed in the upper die, and the stroke required on both forming operations should be such that the press stroke will handle the two with reasonable room for removal, Fig. 4*.

A wide variety of punched, blanked, pierced, notched, formed, and combination designs can be produced on the press brake, see Fig. 5*. Plain holes in nominal sizes from $\frac{1}{32}$ to $1\frac{1}{2}$ in. can be specified in almost any arrangement. However, spacing between holes or from hole to edge of the sheet should usually be $\frac{1}{2}$ in.

*Figs. 2, 3, 4 and 5, as well as part of the text, have been taken from "Press Brake Forming," by Roger W. Bolz, *Machine Design*, June, 1947.



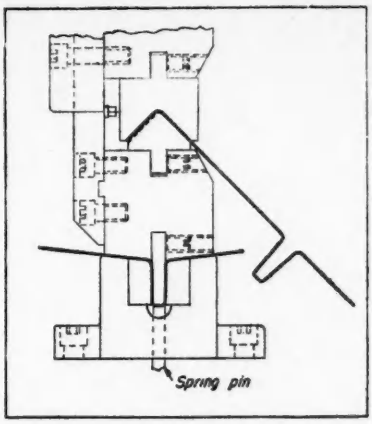


Fig. 4. **Cross-section of a double-deck die for performing two operations.**

or greater, though in certain cases this can be reduced to about one thickness of the stock used.

As usual, consideration must be given to keeping tolerances no closer than the method of manufacture makes practicable. It will be recognized that tolerances readily held in economical production on the press brake must usually be considerably wider than those normally specified in machining, stamping or roll forming. Unless relatively large quantities are involved and expensive special dies are warranted, tolerances on simple sections up to about 6 inches should be around plus or minus 0·030 in., especially

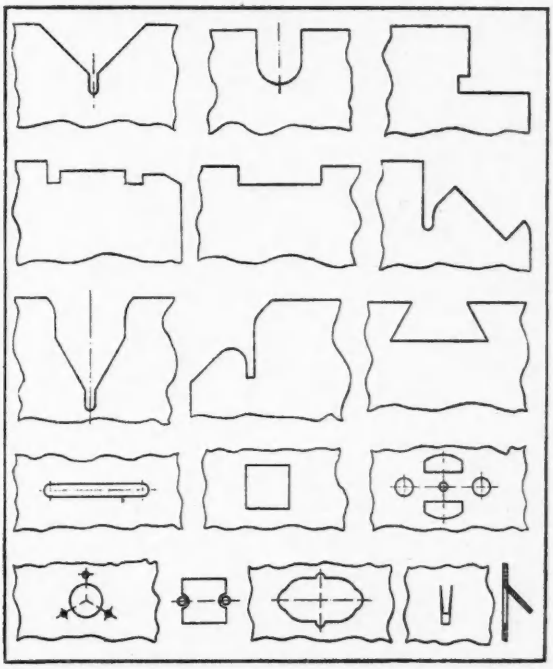
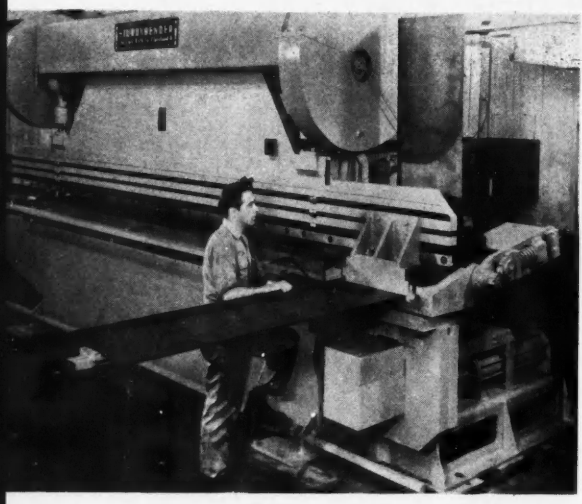


Fig. 5 (above). **Some of the various shapes and hole combinations which can be perforated on the press brake.**

Fig. 3 (left). **Group of representative press brake forming die sets which illustrate the multitude of forms which can be produced.**



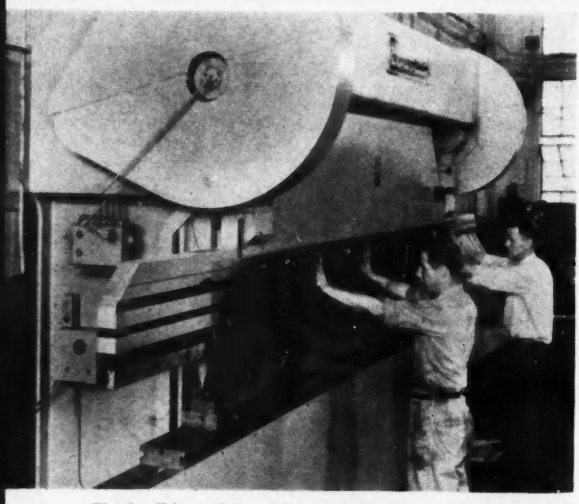


Fig. 8. **Edges of the sheet-metal blanks are flanged in five operations, employing three pairs of conventional press brake dies.**

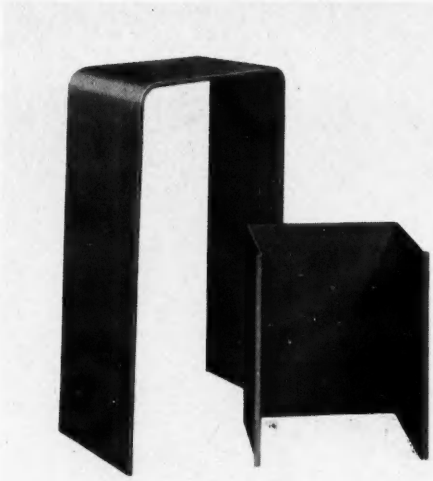
where length is considerable. Naturally, where short parts are produced, say up to 6 ft in length, closer tolerances can be held, but are dependent to a great extent upon uniformity of gauge, temper, etc.

Length tolerances on parts with formed ends should always be generous. Although plus or minus 0·015 in. can be held in some cases where parts are short and of light gauge, specification of at least plus or minus 0·030 in. on small parts, 0·060 in. on medium parts and 0·125 in. on large parts will afford maximum economy and ease of handling. Naturally, tolerance for parts sheared to length prior to forming will depend upon the care and type of shear used, though here again wide tolerances are conducive to maximum economy.

One of the most serious problems in bending flanged metal sheets to form cabinets is the tendency of the flanged metal to wrinkle at the rounded corners of the cabinet. By the use of tangent benders, this problem has been overcome; this type of equipment, however, is not yet extensively used in Great Britain. Many

Fig. 6 (left). **The versatility of the press brake has been increased by the use of a tangent bending attachment, which permits metal cabinets to be completely formed on one machine.**

Fig. 7 (below). **Outer shell and inner liner for a refrigerator. Both parts are flanged and formed on a press brake with tangent bending attachment.**



manufacturers have attempted to overcome the problem by notching the flanges before bending, and later welding the notched flange and, finally, grinding the welded area. This, however, is an expensive and time-consuming operation.

While extremely high production might justify the cost of special presses, the manufacturer who wants to produce up to 200 or 400 units per day can be completely tooled for his production at only a fraction of the cost. By eliminating the notching, welding and grinding, the working time per unit is also greatly reduced. Most significant is the complete elimination of wrinkling by use of this equipment. Advantages offered by tangent benders have recently been described in the journal " Design "[1], and interesting illustrations of various types of Struthers Wells Tangent Bending equipment are given.

An interesting combination of press brake and tangent bender, the " Sturdy Bender," Fig. 6, has recently been introduced by the Cyril Bath Co., of Cleveland, Ohio.

Fig. 7 shows the outer shell and inner liner of a refrigerator with a production of 200 per day on a single Bath press brake equipped with conventional flange dies and a tangent bending attachment. Flat blanks of 18-gauge cold-rolled steel are used. On one edge the blank is bent at an angle of 90 deg. and a standard " V " die is used, as shown in Fig. 8 and, diagrammatically, in Fig. 9.

The sharper bending and flattening of the same edge is done by changing to dies " B " and " C," illustrated in Fig. 9. Die " D " is then employed to complete the triple lock flange on this edge. The same die is used to flange the other edge, as shown in sketch " E " in Fig. 9. The insert shown at " X " is substituted for that shown at " Y." In order to allow for springback after the bending operation, the second flange is bent to an included angle of slightly less than 90 deg. Then, after a number of parts has been flanged, the

[1]H. V. Doren: Streamlining: Fad or Function? *Design*, October, 1949.

tangent bending attachment is employed. This is mounted on the right-hand end of the press, as shown. In order that the press brake may be operated independently of the tangent bender attachment, separate controls are provided. Fig. 10 shows the upper die "A" of the tangent bender bolted to the extended ram " B " on the press brake, while the lower die " C " is mounted on the bed extension shown in " D." The flanged sheet metal blank slides between the upper ahd lower dies while the ram is in its upper position. The blank is located from its outer end by means of a gauge, provided on a channel arm extended from the front of the attachment. The ram is then lowered with a foot pedal to grip the work between the dies. In order that the work shall be clamped before the ram reaches the bottom of its stroke, the lower die " C " is equipped with a spring-actuating pad. An overload protection device is provided, which instantly releases the automatic clutch to disengage the flywheel in case of an overload.

The shoe " E," in Fig. 10, is a guiding wing held horizontally for loading and unloading. It swings through a 90 deg. angle to the vertical position shown, by means of a gear and rack connected to the piston-rod of the air cylinder " F " which can be seen in the lower right-hand corner of Fig. 10. The flat surface of the wing remains tangent to the metal being formed, while the metal is contoured on the lower rear corner of die " A." In the illustration shown, the rounded corners are formed with a 3⅛-in. radius.

The large roller " G " contacts the rear surface of wing " E," keeping that wing in constant contact with the metal being formed, by the action of the heavy car springs " H." Spring tension, of course, is adjustable. The roller moves upward on the wing as it takes its vertical position. In this manner, pressure is constantly exerted on the wing in line with that section of the metal being formed. Buckling is avoided and any temporary wrinkles formed are ironed out, since the metal being formed is tightly confined between the wing and the upper and lower dies. Consequently, the finished cabinet has a smooth appearance on both the flanges and the curved corners forming the crown of the cabinet.

After one corner of the cabinet is formed, the blank is then advanced through the die to make the second bend. The wing then returns to its original horizontal starting position as shown in Fig. 11. The completed part is then removed from the rear of the tangent bending attachment.

This method has been successfully applied in forming cabinets from both cold and hot-rolled steel in 20, 18 and 16-gauge thicknesses. Thinner materials than 20 gauge are avoided in order to eliminate the possibility of tearing the sheets. An adjustment is provided on the upper die, however, to permit the handling of various thicknesses of metal in the same set-up.

With this forming method, flanges are compressed with very little stretching in the body of the sheet. To secure an unwrinkled flange, the flanges as a rule should not be deeper than one third of the radius. For example, if a 3-in. radius is desired without wrinkling, the flange should be kept to approximately 1 in. In cases where the edge of the blank is the triple-flange type, however, as in this case, the flange depth may have to be reduced to ¼ in. or the corner radius may have to be slightly increased. As a rule, stress marks may

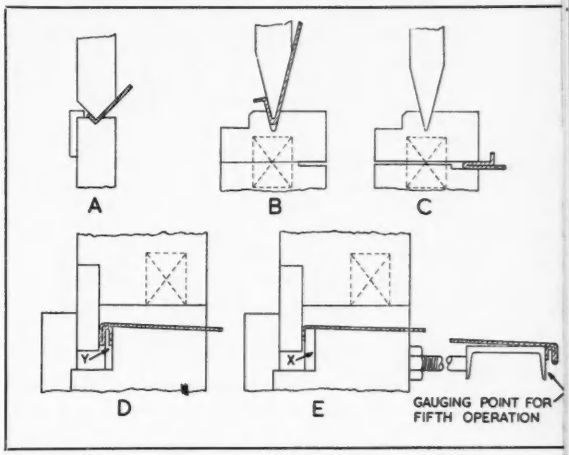
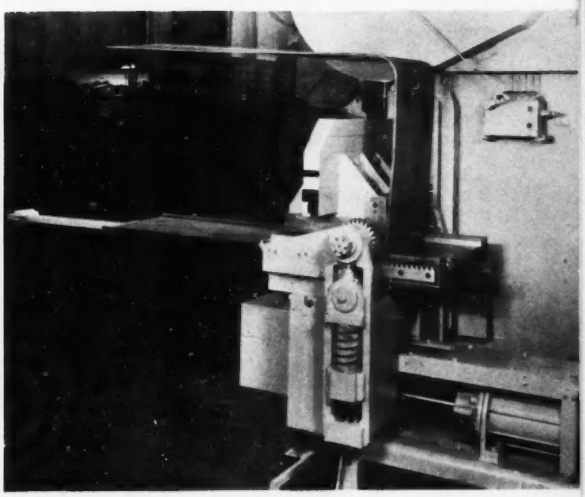


Fig. 9 (above). **Diagram of operation shown in Fig. 8.**

Fig. 10 (below, left). **Tangent bending attachment. Upper die A is bolted to extended ram B, while lower die C is held on bed D of the press brake.**

Fig. 11 (below). **The completely formed cabinet is now ready to be removed from the tangent bending attachment. The rack and gear-actuated wing has returned to a horizontal position.**



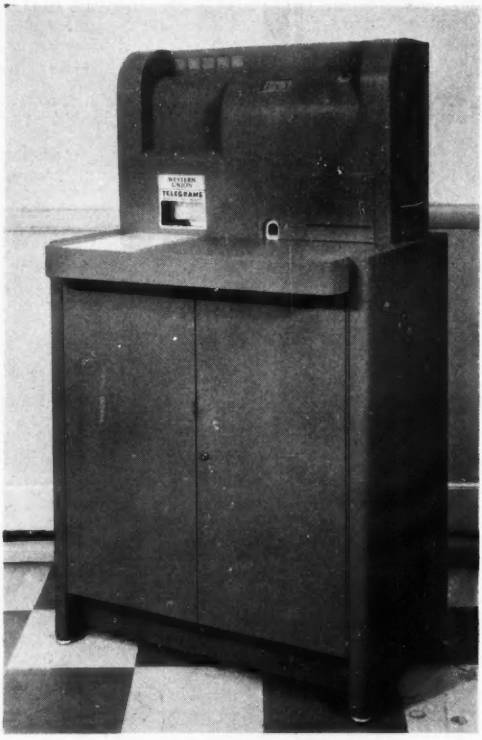


Fig. 12. **"Telefax" cabinet.**

appear on adjoining areas of the sheet only when forming sharper corners than those mentioned above. The tangent bender is more successful if the corner radii are anywhere between 1 in. and 5 ins. However, tangent bending equipment is even available for making bends up to a radius of 12 ins. If greater production is desired, it can be doubled by installing a tangent bender at both ends. When production requirements exceed 200 cabinets per day per machine, it is generally preferable to have a special-purpose unit.

It is interesting to note that tooling for the tangent bender attachment is quite inexpensive. The lower die wing and rack need never be changed. The air cylinder operates on ordinary shop pressure of 70 psi, and the stroke is adjustable anywhere from 0 to 90 deg.

Since the elastic limit of the metal is seldom reached by the stress set up in this method of forming, allowance is generally made in the dies for spring-back after forming. The exact amount of spring-back is determined by running through a few experimental samples. As low-cost dies are used, the dies can easily be reworked after forming a few parts.

So far, we have merely dealt with cabinets which are required in fairly large quantities. It happens quite frequently, however, that a manufacturer is asked to produce only a very small number of cabinets; yet these should be of pleasing appearance and produced within reasonable cost. It is obvious that a different manufacturing technique will have to be adopted. Often, the use of prefabricated standard parts screwed together may entirely eliminate tool and die investments.

If the shape of the cabinet does not conform to simple geometrical forms, that is, if its functional purpose necessitates wide variation in contour, arc welding is likely to prove the most economical process of manufacture. Arc-welded cabinets lend themselves to flexibility in form and design. This flexibility permits the development of a functional yet attractive unit adapted to conform to the requirements of the equipment enclosed.

As an example, let us consider the cabinet for the automatic Telefax[2] machine as shown in Fig. 12. The cabinet is constructed of sheet steel. Rounded contours and recesses, made possible by continuous arc welded joints, were necessary to conform to the requirements of the Telefax mechanism and the coin receiver. Only for arc-welding procedure could the construction of a cabinet of such required variation in contour be reasonably considered. Complexities in contour, however, with smooth, uniformly ground, arc-welded joints in no way detract from the finished appearance.

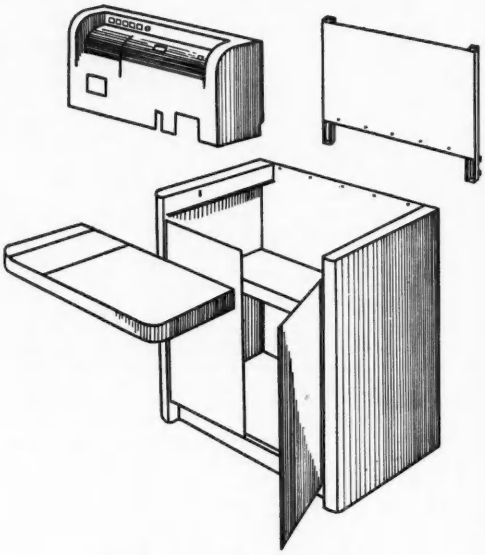


Fig. 13. **Details of "Telefax" cabinet.**

As shown in the exploded view, Fig. 13, the rounded surfaces are joined to vertical clip members by spaced arc welds; similarly, the clip members are welded to the side panels. This joint construction, in effect, provides the strength of a tubular member and a flat rigid surface for welding the doors in place. Continuous hinges were used in preference to spaced butt hinges to improve the appearance.

A toe space, 5 in. high, protects the lower extremity from shoe marks. The toe space is formed by a cross-panel securely welded in place against the side panels, and by an extension of the lower shelf rigidly supported on a channel-cross and welded in place against the side panels. Other parts of the main cabinet are of conventional design with the exception of the 3-in. recess or opening at the top for receiving the writing shelf. The doors are of panel design with rib stiffeners, which are formed for spot welding with a few spaced tack welds near the ends.

The writing shelf consists primarily of a single

(*Concluded on page* 444.)

[2]Telefax is a distant facsimile communication. The description and illustrations of this machine have been taken from V. Weidner's article in the book *Design for Welding*, published by the James F. Lincoln Arc Welding Foundation, pp. 387-391.

Properties of Conductive Plastics

(From *Electronics, U.S.A.*, Vol. 22, No. 10, October, 1949, pp. 96-99, 7 illustrations.)

AN increasing number of engineering problems require for their solution structural assemblies having selected properties of both metals and plastics.

Electrically conductive materials which can be moulded like ordinary plastics and directly plated offer a solution to many of these problems. Quite apart from serving as a base for electro-plating, the materials have other useful and unique applications as engineering materials. Thermosetting, thermoplastic and elastomeric variants have been produced, many of which exhibit enhanced thermo-conductivity and heat stability.

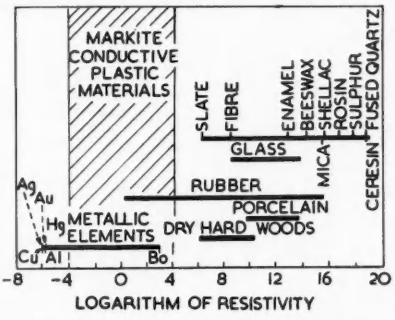


Fig. 1. **Resistivity spectrum of conductive plastic materials.**

As indicated in Fig. 1 conductive plastics have been prepared which encompass a fairly extensive range of resistivity values. Appearances vary from dark, opaque, materials of semi-metallic appearance to completely transparent ones. Most of these materials may be classified as organic plastics and seem to depend chiefly on high polymeric carbon-carbon chains and networks for their plastic structure.

Current costs are of the order of several dollars per pound. Since the moulding operations are normally not conventional and special precautions must be observed, present arrangements are such that parts moulded to the user's specifications will be supplied, rather than moulding powders.

More detailed properties of representative conductive plastics are indicated in the bar-graphs of Fig. 2, which also provide a reference comparison with the familiar general-purpose phenolics. In order to have a more specific yardstick and a cross-check on the test methods, specimens of a single typical general-purpose phenolic were included as test controls. From Fig. 2, which is self-explanatory, it will be seen that the new conductive material behaves like the reference phenolics with respect to all of the general and mechanical properties. As regards thermal properties, it is of importance that the thermal expansion coefficient is in the range of general-purpose phenolics permitting the combination of the two plastic materials without shrinkage difficulties. Composite mouldings of both materials exhibit good integral bonding characteristics.

Electrical conductivity is of the order of 10^{12} times that of the general-purpose plastics, and definitely in the range of the substantial electrical conductors. However, low resistivity is in itself of little value for most electrical applications unless reasonable predictability and reproducibility of behaviour with respect to the chief operating variables can be expected. Important variables include temperature, current density, duration of loading and frequency. The resistivity increases in a simple and essentially linear manner with increasing temperature, as indicated in Fig. 3. The temperature coefficient of resistivity of approximately +0·2 per cent per degree C is, for many purposes, desirably low. The value is roughly one half that of the most familiar conductor materials—copper, silver and aluminium.

The effect of current density on resistivity is indicated in Fig. 4. For current density up to about 16 A/cm², the resistivity is independent of the current density and the material follows the simple Ohm's

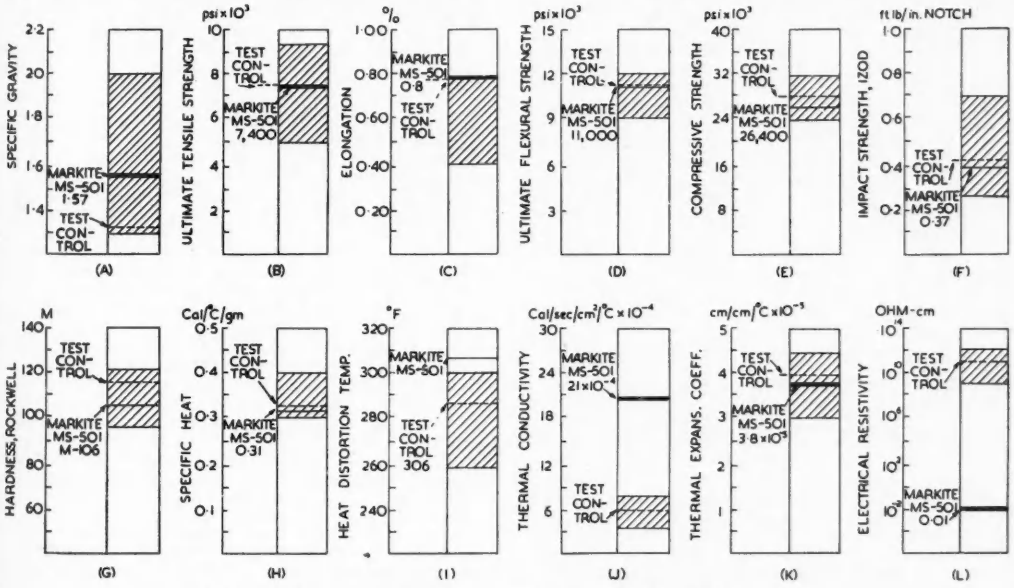


Fig. 2. **Twelve properties of a representative conductive plastic material.**

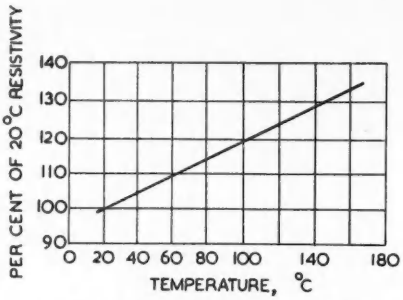


Fig. 3. **Effect of temperature on resistivity.**

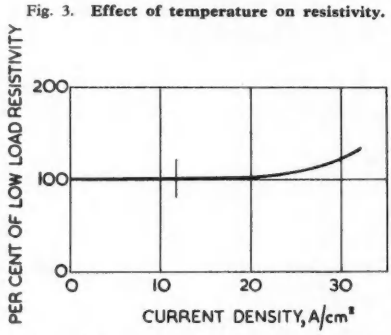


Fig. 4. **Effect of current density on resistivity.**

law. In the neighbourhood of 30 A/cm² destructive pyrolysis appears to take place. At lower current densities the behaviour is reversible and resistivity values check on repeated testing cycles. The increase of resistivity in the 10-30 A/cm² band is primarily a temperature effect. At moderate and low current densities, the resistivity is stable and apparently exhibits no tendency to drift or vary significantly after an appreciable number of hours of continuous loading.

For the range from d.c. to 40 Mcps, resistivity appears to be independent of frequency.

A number of these conductive plastics are compatible with each other and can also be blended with certain conventional insulator plastics to yield materials of intermediate resistivity. Predictable and reproducible variations can also be secured, within limits, by the incorporation of different fillers and plasticisers and modifications of the processing methods. It is thus possible to produce plastics of prescribed resistivities over a substantially continuous range of values. The extent of this range has been indicated in Fig. 1. It is thus feasible to design materials having any desired resistivity from approximately 1 megohm-cm to less than 1 milliohm-cm. There is evidence that the range may be extended upwards to at least 1 million megohms and probably may be extended downwards to values approaching 10 micro-ohms.

Resistivity values for a number of specific conductive materials are given in Fig. 5. Of those listed, MP-401-8, MP-401-11, E-473 and M-485 are thermo-plastic; the others are thermo-setting. A unique member of the series is E-473, which has distinct rubber-like properties, but 1000 times the conductivity of the highly conductive rubbers.

In many applications, such as devices intended for aircraft use, low total weight is particularly desirable. Similarly, low density is often desired of parts which are to be rotated at high speeds in order to minimise centrifugal stresses. The favourable conductivity/weight ratios of a number of conductive plastics commend them for such purposes. The strength/weight

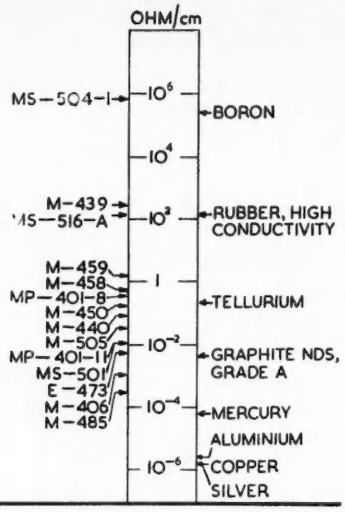


Fig. 5. **Resistivity values of various conductive plastics.**

ratios also compare favourably with those of metals.

Due to the wide range of resistivities, a wide range of resistances may be secured by merely varying the path length and cross-section. It is just as easy to mould a tapered resistor or the key-member of a tangent potentiometer as it is to mould a plain uniform linear resistor. Cooling fins can be moulded integrally. Many devices, such as certain wave guide auxiliaries, attenuators and pads, require high surface conductivity, and often intricate shapes are involved which demand elaborate machining and close tolerances. Conductive plastic parts precisely moulded and directly plated with silver are promising for such applications. There is evidence that wide but controllable variations of resistivity with temperature may be designed into these conductive plastic materials.

Static electricity is a frequent source of annoyance. Storage containers, casters, handles, funnels and laboratory appliances, in general, moulded from conductive plastic materials, will not build up undesirable static charges. Cabinets, instrument cases and related articles may be simultaneously furnished with shielding properties at the time that they are being moulded on a mass-production basis.

By composite moulding of compatible conductive and ordinary plastics of matched temperature coefficients, composite assemblies may be fabricated in which the joints and interfaces are liquid-tight and gas-tight and will remain so over a wide temperature range. Two or three-dimensional electric circuits can also be moulded. Instead of requiring a panel on which to mount wires and terminal equipment, or to print a circuit with conductive ink, the wiring itself may be moulded, threaded, tapped and heat-bonded to provide a compact and adequate support for valves, capacitors and other parts. Certain conductive plastics may be soldered to directly. Such moulded circuits may be used by themselves or in co-operation with printed and other circuits.

Plastic commutators are special examples of moulded three-dimensional circuits. Apart from simplified fabricating procedures, possible advantages include the natural tendency for matched plastic conductors and plastic insulators to wear down together more uniformly. By similar matching of thermal expansion coefficients, close relative dimensional tolerances may be preserved over a wide temperature range.

CLASSIFIED ABSTRACTS

Numerous important abstracts which, for lack of space, cannot be published in our main editorial columns, are regularly included in condensed form in this section. Subscribers may obtain photostat copies of all original articles at cost.

CLUTCHES

Magnetic Fluid Clutch in Servo Applications

By A. NELSON. (From *Electronics, U.S.A.*, Vol. 22, No. 11, November, 1949, pp. 100-103, 10 illustrations.)

THE possibility of using the magnetic fluid clutch* in servo-mechanisms has led to a thorough investigation of this device. The following general conclusions were reached: 1. The natural frequency of a servo-mechanism incorporating magnetic fluid clutches depends on the design and dimensions of the latter. Using, for instance, a clutch of disc design, the rotor having a diameter of 3 in. and a thickness of 1/16 in. and the magnetic fluid cavity being 1/16 in. in width, the natural frequency is below 30 cps. This limit is mainly due to the transient speed response of the clutch, 0·007 second being the smallest time lag obtainable with the clutch tested; the time of rise to 1620 rpm of 0·02 second was the maximum obtainable acceleration. Various diagrams give detailed test results which also show that the dead time depends to a great extent on the applied exciting voltage. 2. Maximum transmitted horse-power with rotor and stator locked is limited only by the size and strength of the structural materials used. 3. Maximum transmitted torque with slip between rotor and stator depends primarily on the ability of the clutch to dissipate large quantities of heat. 4. For a 3-in. single-disc clutch, speeds below 3000 rpm give no trouble from a centrifugal packing of iron on the rotor periphery. The effect of centrifugal forces on the fluid—iron powder mixture and thereby on the torque can become very pronounced if the clutch has been running idle for some time. This effect as well as the influence of the viscosity of the magnetic fluid on the performance of the clutch are illustrated by diagrams. 5. A high nickel steel should be used for stator and rotor to eliminate adverse effects of hysteresis on these components. 6. An increase in torque using the same excitation current, and an improvement in general characteristics, can be obtained by using rotor discs with concentric holes near the periphery. 7. Magnetic fluid clutches are not recommended for use on spring loads unless provision is made for heat dissipation. 8. The ratio of residual torque to maximum torque varies according to design, but in the case tested, this was about 6 to 1000.

A servo-system with magnetic fluid clutch for quick response used as a voltage-multiplying device is described, and the electrical circuit diagram is shown.

*See also *The Engineers' Digest*, August, 1948, pp. 260-261.

PHOTO-ELECTRIC CONTROL

A Method for Determining the Mercury Content of Air

By H. VAN SUCHTELEN, N. WARMOLTZ and G. L. WIGGERINK. (From *Philips Technical Review, Holland*, Vol. 11, No. 3, September, 1949, pp. 91-97, 5 illustrations).

EXPOSURE for some length of time to an atmosphere contaminated with mercury vapour may be dangerous for human beings when the air contains more than 100 μg mercury per m^3, as established by American scientists. The method described in this article for determining the mercury content of air is based upon the property of the mercury atom to absorb radiation of the wavelength 2537 Å. Part of this radiation, supplied by a low-pressure mercury-vapour lamp, passes through a measuring tube, through which the air to be tested is conducted and is then directed upon a photocell, whilst another part is thrown directly upon a second photocell. The two photo-electric currents are compared by means of a compensation circuit, with a tuning indicator used as zero device. The two methods by which the apparatus described is calibrated are briefly discussed. Mercury concentrations of 1 to 200 per cent of the limit dangerous for human beings can be measured. Various possibilities of application are mentioned. This mercury-vapour detector appears to be sensitive also to all kinds of organic vapours, but to a much less degree compared to mercury, so that this does not cause serious interference. Advantage can be taken of this property of the detector for measuring also the concentration of these organic vapours.

REFRIGERATING ENGINEERING

Artificial Cooling in the Laboratory and in Industry.

By H. DIETLER. (From *Elektrizitätsverwertung, Switzerland*, Vol. 24, Nos. 6/7, September/October, 1949, pp. 136-140, 14 illustrations.)

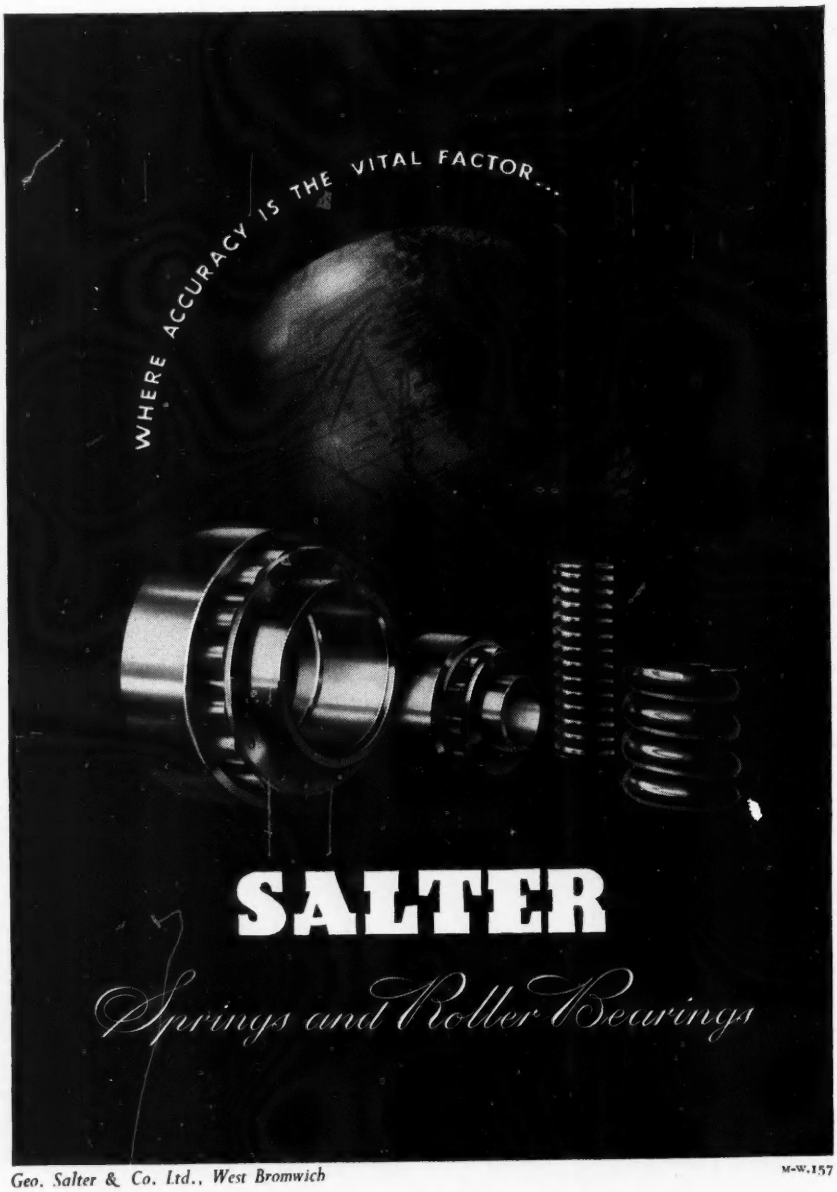
THE article gives a survey of some more recent applications of artificial cooling, mainly in the engineering industry.

By a deep-freeze treatment, i.e., by quenching steel from room temperature to about—80° C, a transformation of the structure of the steel takes place, in which austenite is transformed to martensite. This produces not only an improved, but also an almost entirely homogeneous hardness. Tools, machine parts, etc., made of such steel show a durability 50 per cent higher than that of corresponding parts not so treated. For instance, a drill which could be used for drilling 500 holes could be used for 800 after deep-freeze treatment. In addition, contrary to the effects of heat treatment, the deep-freeze treatment causes no internal stresses and consequent changes in dimensions. Instead, the structure is stabilized so that parts treated will keep their true shape longer. This is especially important for gauges and for work to very close tolerances.

Instead of shrinking with a bore on to a shaft by heating until the bore has expanded sufficiently, the shaft may be cooled so much that its reduced diameter will enter the bore. Changes in shape or in physical or chemical structure due to heating can thus be avoided.

Precision apparatus, especially for aircraft, is often tested at very low temperatures (—60° C) and pressures corresponding to actual conditions when flying at extreme altitudes.

By cooling lubricants used for machining operations (high-capacity lathes, drills, etc.) to about 5° C, output can be increased by as much as 50 per cent, as higher speeds are permissible without overheating the tools. At the same time, evaporation of the lubricant is reduced or eliminated.



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STRESS ANALYSIS

Stress Increase and Stress Reduction by Arrangement of Multiple Notches.

By A. THUM and O. SVENSON. (From *Schweizer Archiv, Switzerland*, Vol. 15, No. 6, June 1949, pp. 161-174, 32 illustrations.)

ANY sudden reduction in the cross-section of a stressed material by means of a groove or a hole leads to stress concentrations and increased maximum stresses. If, however, several such grooves or holes are arranged in series in the direction of the flow of force the stress disturbance and, therefore, the maximum stresses may again be slightly reduced. It is known, for instance, that a single thread of a screw has a worse notch effect than several threads. Notches arranged in parallel i.e., side by side, transversely to the flow of force, may increase the maximum stress, or leave it unchanged, or even reduce it. In general, if the distance between notches or holes is sufficiently large so that the ensuing stress disturbances do not interfere with each other, the maximum stress is not appreciably affected unless the total unnotched cross-section is reduced by more than 20 to 30 per cent. Thus, if a plate or tube under tension contains one small transverse hole, two or three other holes can be arranged side by side with the first one without any effect on the value of the maximum stress. Semi-circular notches at the side of a plate under tension do not increase the maximum stress as much as does one hole at the centre of the plate width. In certain cases, the addition of such side notches may even reduce the maximum stress in a plate with a central transverse hole, inasmuch as regions with low stresses are then carrying higher stresses and take a greater part of the total load. As soon as the stress disturbances of the separate notches interfere with each other, the maximum stress increases appreciably. Very high stresses appear if narrow bridges of material are left standing between notches or holes, or between one notch or hole and the smooth edge of a piece. If these bridges stand on their own (hole drilled near the edge of a plate), their failure does not necessarily lead to the destruction of the whole specimen. If, however, a local crack can spread into adjacent material (oil hole in a crankshaft drilled too near the crank edge), total fatigue failure ensues. The maximum stress at the root of a notch is also increased when the lower stresses in the remaining cross-section are further reduced by notches or holes arranged in neighbouring cross-sections (Z-arrangement of rivet rows).

Stresses due to bending are not uniform over the whole cross-section, but fall towards zero at the neutral fibre. A small transverse hole at the neutral axis may, therefore, slightly increase stresses at the edge of the hole and, thus, in its total effect, *reduce* the maximum fibre stress at the outside of the reduced cross-section. The resulting stress disturbances, however, extend over the neighbouring cross-sections, and here the maximum fibre stresses are increased because of the disturbance—given that the bending moment is constant over the affected length. Bending fatigue fractures in bars with a small transverse hole at the neutral axis do in fact occur outside the reduced cross-section and do not touch the hole. If the bending moment is not constant over the test length, a small transverse hole at the point of highest bending moment may well increase the fatigue strength of a bar ! As the diameter of the transverse hole increases up to one half of the total depth of the bar, the stresses at the edge of the hole increase and finally exceed the maximum outside fibre stress ; the overall strength of the bar is then again reduced. If a bent bar has a transverse hole in the plane of the bending moment, then an additional transverse hole in the plane of the neutral axis (perpendicular to, and intersecting, the first hole) may reduce the stress concentration, but cannot reduce the absolute maximum stress, as the decrease of the total section modulus outweighs the advantages gained from the point of stress concentrations. The crossed transverse holes may, however, increase the fatigue strength of a rotating bar under bending forces as compared with that of a bar with a single transverse hole. The reason is the reduction of the stress fluctuations, since the section modulus does not vary as extensively with the rotational position of the bar. This effect is dependent on the force distribution, stiffness, and speed of the system.

Notches or holes arranged in three dimensions at, or in the vicinity of, one cross-section lead to interference of their separate stress disturbances and, therefore, to increased maximum stresses. The resulting effect cannot easily be determined experimentally and does not correspond to a superposition of the separate effects. The authors have evolved an approximate method of calculating the combined effect based on the stresses in bent plates with transverse holes. The material at the root of one notch is considered to be part of such a bent plate, the additional notch being compared, in its effect, to the hole of a corresponding flat plate. The thickness of the substituted bent plate is obtained from the stress gradient in the immediate vicinity of the root of the notch.

Points of attack of concentrated loads are always points of stress concentrations and disturbances. Any notch in the immediate vicinity of such a point must lead to increased maximum stresses. These types of stress concentration are very frequent and appreciably affect the fatigue strength of the part. Typical examples are screws, bolt heads, rivets, etc.

Some Aspects of Cabinet Design and Production

(*Concluded from page* 440)

sheet to form the top, sides, back, and front, including the part of the bottom which overhangs the front surface of the cabinet. Separate pieces are required for the construction of the sunken tray, door stop, and spring catches. It is the large single sheet which, in a sheet metal shop, readily lends itself to fabrication by arc welding. The steel is punched in the flat, allowing material to form the top, sides, back, front and bottom flanges. The complete shelf slips snugly into place in the recess of the main cabinet and is firmly held by spring clips.

It is not possible, in the limited space at our disposal, to give a complete picture of all factors with which the cabinet designer may be confronted. Surface finish, for instance, which is a very important subject, had to be omitted entirely, although it affects appearance to a considerable extent.

In conclusion, it may not be out of place to say a few more words about appearance design. Our American friends sometimes refer to it as " styling for sales appeal," or " streamlining," and the latter term has also been used in Great Britain, mainly by those who are not familiar with the meaning of streamlines. A manufacturer who calls in an industrial designer to have his products " streamlined " really means to have them modernised. To those who frown upon industrial design and regard it merely as a fad, we may answer with Van Doren's words[1] " Much so-called streamlining is imposed on the designer by the necessity of obtaining low cost through high-speed production. What may thus appear to be a captious preference for voluptuous curves and bulging forms in place of a more athletic spareness, proves to be one result of the evolution of fabricating methods and assembly-line techniques."

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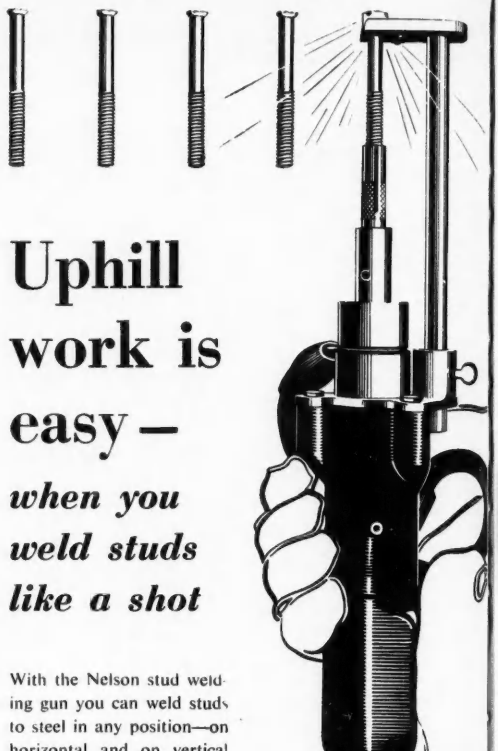

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NEWS OF THE MONTH

PERSONAL.

Mr. W. Adam, B.Sc. (Eng.), A.M.I.E.E., has been appointed to succeed the late Mr. J. Miller as Manager of the Glasgow district office of The British Thomson-Houston Co., Ltd.

Mr. C. H. Bradbury, M.I.C.E., M.I.Mech.E., has been appointed chief engineer of Petters Ltd., Small Engine Division, Staines, Middlesex.

Mr. N. G. Cadman has been appointed deputy works manager (engineering); **Mr. K. H. Leech,** chief mechanical engineer; **Mr. C. F. B. Shattock,** deputy chief mechanical engineer (design); **Mr. J. W. Kershaw,** deputy chief mechanical engineer (brakes); and **Mr. H. M. Hoather,** brake equipment engineer of the Westinghouse Brake and Signal Co., Ltd., 82 York Way, London, N.1.

Professor H. D. Conway, Cornell University, Ithaca, N.Y., has been awarded the D.Sc.(Eng.) degree of the University of London.

Mr. C. F. Gimson has been appointed manager of the control-gear engineering department of the British Thomson-Houston Co., Ltd., Rugby.

Mr. Stewart Scott Hall has been appointed director general of Technical Development (Air) of the Ministry of Supply.

Colonel L. C. Hill, D.S.O., M.C., B.Sc., A.R.S.M., has been elected President of the Institution of Mining and Metallurgy, Salisbury House, Finsbury Circus, London, E.C.2.

Mr. J. Houldsworth, A.M.I.Mech.E., has been elected technical director of A. A. Jones & Shipman Ltd., Leicester.

Mr. Trevor Jenkins, M.I.Struct.E. has been appointed acting chief engineer of Guest Keen Baldwins Iron and Steel Co., Ltd., East Moors, Cardiff.

Mr. G. Mackenzie Junner, F.R.S.A., M.I.Mech.E., has been re-elected Chairman of the Institute of Road Transport Engineers. **Captain C. F. Roberts, M.C., M.I.Mech.E., Mr. N. G. Brookes, M.I.Mech.E.,** and **Mr. W. E. Smith** have been elected vice-chairmen.

Rear-Admiral (E) D. C. Maxwell, C.B., C.B.E., M.I.Mech.E., F.R.S.A., has been appointed Engineer-in-Chief of the Fleet.

Mr. James Mowat, B.Sc., F.I.M., chief of research, has been appointed special director of William Beardmore and Co., Ltd., Parkhead Steel Works, Glasgow, E.1.

Mr. H. G. Nelson, A.M.I.C.E., A.M.I.Mech.E., A.M.I.E.E., has been appointed deputy managing director of the English Electric Co., Ltd. He will relinquish his position as managing director of D. Napier and Son, Ltd., but will retain his seat on the Board. **Mr. H. Sammons, M.I.Mech.E., F.R.Ae.S.,** has succeeded Mr. Nelson as managing director of D. Napier and Son, Ltd.

Mr. C. A. P. Southwell, M.C., B.Sc., has been elected President of the Institute of Petroleum, 26 Portland Place, London, W.1.

Mr. R. Ewart Stavert, President of The Consolidated Mining and Smelting Company of Canada Ltd., who is also on the Board of Dominion Bridge Co., Ltd., Dominion Engineering Works Ltd., and other companies, has been elected a director of The International Nickel Company of Canada Ltd.

Mr. Bernard Tebb, M.I.Mech.E., works manager of the Mastabar Belt Fastener Co., Ltd., has been appointed to the board of the Company.

DIESEL-DRIVEN UNDERCAR POWER PLANT FOR RAILROADS

A NEW diesel-driven undercar power plant for railway passenger car auxiliary power has been developed in the U.S.A. by the General Electric Company. Rated 30-kW, the unit is designed for mounting underneath any new or rebuilt passenger cars with sufficient clearance to allow unrestricted movement on any railroad in America.

The power plant consists of a 50-hp Buda diesel engine and an alternator that provides 220-volt, three-phase, 60-cycle power. The 4-cycle engine has a displacement of 273 cubic inches. The alternator has a maximum gross rating of 33·8-kva and with its ultra-high speed amplidyne exciter and static-type regulator, has been designed to handle the present-day car loads with power to spare.

One of the major advantages of this type of plant is the elimination of the load on the locomotive which is produced by axle-driven generators. It has been estimated that as much as 20 per cent of the load on a passenger train locomotive under limiting conditions of acceleration will be the axle generator drag. Faster train schedules and longer trains will be possible when the diesel power plant is applied.

Although the diesel-driven set weighs 4800 pounds, the increased weight of the batteries, cable, air conditioning motors and drive unit necessary with an axle-driven generator make the diesel-driven set lighter than the conventional undercar power plant.

A unique mounting arrangement on the new G-E power plant makes maintenance easy by enabling the power plant to be swung out of the box and out from under the car.

Engine water is cooled by a separately-mounted radiator which is blown by a motor-driven, propeller-type blower. The operation of the blower is controlled by a thermostat so that the engine water temperature is held between desired limits.

Noise from the power plants has been minimized through special insulation and mounting so that it is practically impossible to hear the plants from the inside of the car. The inside of the box and the air intake and outlet ducts are sound-insulated and the box is suspended on rubber mounts. The power plant is doubly isolated by being suspended on rubber within the box.

The power plants have been designed to operate in parallel so that an entire train can be train-lined, thus assuring maximum reliability. The alternators are designed so that no synchronizing equipment is needed to parallel sets.

Another advantage of the sets is the relief that can be given the diesel-electric locomotive steam boilers. The 30-kW diesel generator not only affords about 20-kW of electric heat but also makes available a large supply of potential heat in both the engine jacket water and the engine exhaust. It is estimated that an efficient car heating equipment will be able to recover about 18-kW of exhaust heat and about 25-kW of waste heat from the jacket water. This means about 214,000 btu total heat available for heating the passenger car.

The power plants are the result of years of research and development and have been proved under months of operation with trial installations. The Illinois Central Railroad has two sets operating on its new all-electric dining car and new equipments are already being built for other railroads.

STANDARDIZING MINING EQUIPMENT

INCREASED efficiency through standardizing of many types of mining equipment are being achieved by the National Coal Board. The Board have representatives on more than 50 British Standard Institution committees, drawn from manufacturers, consumers and other increased bodies which deal with many pieces of equipment from nuts and bolts to locomotives.

The N.C.B. control nearly 1,000 collieries. When they took over the mines, for instance, there were in use about 100 different types of arch rings (used for roof support on underground roadways in place of the old-fashioned prop and top). About 2 million rings weighing a quarter of a million tons are used every year. Under the process of standardisation types of arch rings have been reduced to about 25 and it is hoped to bring them down further.

About 40,000 tons of light rails covering a thousand miles of

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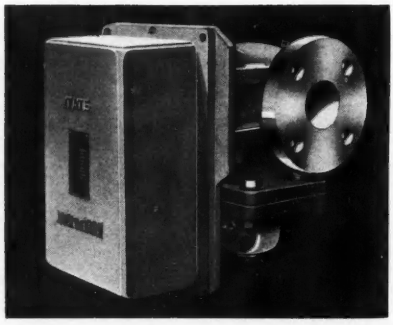

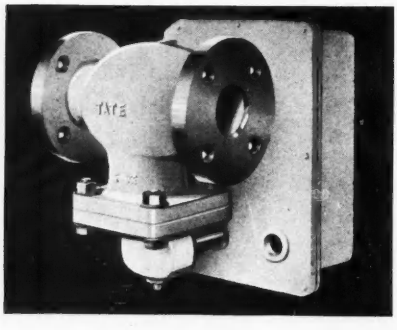

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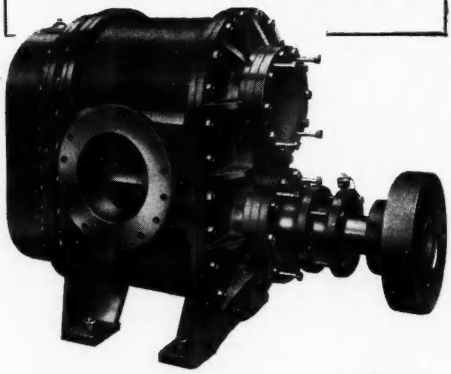

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single track are laid each year in the mines. It is hoped to reduce the 20 types in the old standard to about six.

The Board have already produced a standard range of solid and drop-bottom mine cars, and a standard prefabricated washery. In addition to light rails, attention is being devoted to guide rails, tub wheels, arch sections, surface steam locos, fire-fighting and dust suppression equipment, electric motors, miners' lamps and winding and haulage ropes.

Further standardization will shortly be undertaken to cover tubs, tracks, cables, conveyors, rope pulleys, shaft and safety harness, and pithead baths fittings.

AGREEMENT BETWEEN THE GOVERNMENT OF INDIA AND STANDARD TELEPHONES AND CABLES LIMITED.

The Government of India has concluded an Agreement with Standard Telephones and Cables Limited, London, for the establishment of a factory in India for the manufacture of all of the Country's requirements of communications cables, including those for subscriber-to-exchange connections, for long distance trunk circuits and for multi-channel transmission systems.

The Agreement is for a period of twenty years during which time Standard are appointed Technical Consultants to the Indian Government, who will thus have the benefit of Standard's vast experience in the telephone cable manufacturing field and freedom to use in the Indian factory all of Standard's present and future cable patents. In return Standard will be permitted to use in their own factories any patents or improvements in manufacturing technique which may emerge from the Indian factory.

The factory and plant—all of which will, it is expected, be purchased in Great Britain—will be Government owned and operated employing eventually all Indian staff and operatives. It is anticipated that the output of the Unit will reach a value of £750,000 per annum in some three or four years time and provision will be made for the inclusion of facilities for the manufacture of new types of cable as these are developed.

Standard will advise the Government on the design of the factory and will prepare the plans for the layout of the plant, much of which will be to Standard's own specifications. Indian manufacturing and technical staff will undergo a detailed course of training and instruction in the Standard factories in England but Standard will also provide from their own organisation key personnel who will assist the Government until the factory is in full operation.

Though the manufacturing programme for the factory will be based primarily upon the Indian Government's own requirements, the Government has the right to supply telephone cables from its factory to the Administrations of Burma, Ceylon and Nepal, as well as to the non-Government market in India. Of any of the telephone cable demands of the Government which cannot be produced in its own factory, Standard Telephones and Cables Limited will normally supply the requirements.

BUSINESS NOTES.

The 40th Anniversary of Woods of Colchester Ltd. was celebrated recently by a dinner at which the guest of honour was Sir Harry Railing, Chairman of The General Electric Co., Ltd.

From a small beginning in 1909 the Company has grown into the largest single works in the world specialising solely in the complete manufacture of propeller and axial flow fans, including the electric driving motors.

Some 70,000 fans produced by Woods of Colchester annually, include Aerofoil fans with contra-rotating impellers developing static pressures up to 7 ins. water gauge; propeller fans up to 72 ins. diam; Auxiliary Mines, man cooler fans and other types.

Drysdale & Co., Ltd., have arranged to use the Engineering Centre, Glasgow, as a permanent showroom and now have on display a selection of Land and Marine Pumps and Steam Engines. An interesting departure from the normal finish of industrial machinery is their use of a variety of bright colour finishes.

"Doncaster Can Engineer It," an Exhibition of Engineering Products made in Doncaster, will take place in the Technical College from the 4th to the 11th February, 1950. The Exhibition will be open until 9 o'clock each evening. In addition to showing actual manufactures, firms will exhibit machines in motion and there will be a series of film shows.

"Welded Bridges of the Future." To promote the building of better bridges for less money the James F. Lincoln Arc Welding Foundation is sponsoring the second "Welded Bridges of the Future" programme.

A first award of $5000 (£1,786) will be made for the best design submitted of a welded 250 foot highway bridge. The second award will be $2500 (£893), the third $1250 (£449). Ten honourable mention awards of $200 (£72) each will also be given bringing the total to $10,750 (£3,839). Any designer or engineer is eligible for participation. The competition closes June 30th, 1950.

Rules and Conditions may be obtained from the James F. Lincoln Arc Welding Foundation, c/o Lincoln Electric Co., Ltd., Broadwater Road, Welwyn Garden City, Herts.

Magnetism Birmingham 12 is the new telegraphic address of The Rapid Magnetting Machine Co., Ltd., manufacturers of permanent and electromagnetic separating and lifting equipment, Lombard Street, Birmingham 12.

BOOKS

The Electron Microscope and Its Application to Materials Problems. 48 pages. $1.25 per copy. Publishers: Technical Services, U.S. Department of Commerce, Washington 25, D.C.

A basic introduction to the nature of the electron microscope, and its contribution to various types of materials problems.

According to the manual, the ability of the electron microscope to reveal visually the size, distribution and shape of particles in the submicroscopic region (less than 1/100,000th of an inch) is of particular importance in accounting for many of the physical and chemical properties of materials. An explanation is provided of the limitations of light microscopes in this realm.

In addition to a theoretical discussion of the problem of image resolution, the manual provides practical information of the construction and operation of the electron microscope, and the preparation of replicas and specimens.

Typical applications of the electron microscope to the examination of finely divided matters and aggregates and to the inspection of surface details of metals, ceramics, and finishes are discussed. Possible future prospects for such fields as lubrication studies are mentioned.

The report contains a number of photomicrographs as well as graphs and illustrations.

"An Introduction to the Dynamics of Compressible Fluids," an Air Force training course, is now available at $20 in photostat form, $6 in microfilm, from the Library of Congress, Photoduplication Service, Publication Board Project, Washington 25, D.C.

The course, originally given at Brown University in 1946, was designed to equip beginners in the study of hydrodynamics for further work in gas dynamics research. The course presents basic principles and discusses types of problems and their solutions.

Among new developments discussed are variational principles and hodograph methods.

Main sections of the course deal with basic relations in gas dynamics: propagation of plane disturbances; steady flow through channels; steady subsonic potential flows; flows involving supersonic regions; wave propagation in a barotropic fluid; compressible flow involving viscosity; and compressible boundary layer on a flat plate.

BRITISH STANDARDS

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Methods for the Analysis of Iron and Steel. The following additional parts to B.S. 1121 have now been published:—

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